

G R O W T H O R D E C A Y

[replacing Pickering's aged nuclear reactors]

by Kelly A. Hann

*A thesis submitted to the Faculty of Graduate
and Postdoctoral Affairs in partial fulfillment
of the requirements for the degree of*

Master of Architecture [M.Arch]

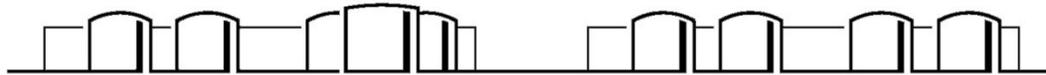
*Carleton University
Ottawa, Ontario*

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GROWTH OR DECAY

[replacing Pickering's aged nuclear reactors]

K e l l y A . H a n n 2016/2017



Thank you to my thesis advisor, Greg Andonian, for his guidance, and continued support through all phases of this research and design work, as well as his suggestions and contributions along the way. And to my family and friends for their great support and continuous encouragement during the journey.

ABSTRACT

Nuclear power plants have existed for around 60 years. Even now, following the Fukushima Daiichi Plant meltdown, they continue to be constructed; leading to the possibility of further nuclear calamity. In the event of a disaster, the resulting nuclear fallout zone can span distances of more than 30 km; but what happens to the facilities that are lucky enough to reach the end of their lifespan? What will become of all the aged nuclear facilities? As the world begins to understand the importance of looking towards renewable energy sources, there are still those that cling to the idea that nuclear energy is the answer, even here in Canada.

How can decommissioned nuclear power plants provide opportunities for renewable growth?

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*"Even with the best intentions, you can have a nuclear war, a nuclear holocaust,
through miscalculation, through accidents."*

*Mohamed ElBaradei
[Director General of the International Atomic Energy Agency, 1997-2009]*

INTRODUCTION

In his text *The Question Concerning Technology*, Martin Heidegger discusses technology as a means to an end; in other words a human activity, as to posit ends and procure and utilize the means to them is profoundly human:

"The manufacture and utilization of equipment, tools, and machines, the manufactured and used things themselves, and the needs and ends that they serve, all belong to what technology is... Even the power plant with its turbines and generators is a man-made means to an end established by man."¹

Heidegger argues that we now view nature, and increasingly human beings too, only technologically — that is, we see nature and people only as raw material for technical operations. He believed that everything in current existence is connected, and is fundamentally united by the basic fact of our common being; believing that this value can bring a more profound appreciation of the brief time that we have here. Humankind has forever reached for the mantle of power by virtue of technology, but to escape our subjugation of it, Heidegger argues it must not be rejected, but its danger must be perceived.²

1 Heidegger, Martin. Edited by David Farrell Krell. "Basic Writings." Pg.312.

2 Blitz, Mark. Understanding Heidegger on Technology. www.thenewatlantis.com

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For decades, scientists have warned that we are on a dangerous path. Our unawareness of this fact stems from the delusion that endless growth in population, consumption and the economy is possible, and is the very purpose of society. But endless growth is not feasible in a finite biosphere; growth is not an end but a means.³ In an online post by renowned environmentalist David Suzuki, he states:

“Humans are one species among countless others to which we are connected and on which we depend.... But in assuming the mantle of “dominant” species, we’ve shifted to thinking we’re at the centre of everything. This anthropocentric perspective leads us to imagine our needs and demands supersede those of the rest of nature.”⁴

Yet we remain dependent on clean air, water, soil, and biodiversity.

We are accelerating the degradation of the very source of our livelihood through massive use of pesticides, artificial fertilizers, nuclear radiation and literally tens of thousands of different molecules synthesized by chemists. These releases into the environment eventually find their way back to us, with scientists suggesting that up to 90 per cent of cancers are

³ Suzuki, David. Anthropocentric view ignores crucial connections. www.davidsuzuki.org

⁴ Ibid.

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caused by environmental factors.⁵

Our reliance on fossil fuels and non-renewable energy sources has led to a new geological age; the Anthropocene*; an age during which human activity has been the dominant influence on climate and the environment. Conclusive evidence has been provided revealing the diminishment of old-age arctic sea ice, heavy drought, and massive species extinctions and endangerments. This substantiation has resulted in the first of its kind: the Paris Agreement; an agreement within the United Nations Framework Convention on Climate Change (UNFCCC) undertaking the collective effort of all parties involved towards the contribution of enhanced support in assisting in the fight against climate change. This agreement is a step in the right direction; pushing the transition from non-renewable to renewable energy sources, and promoting the advancement of green technologies.

Unlike the fossil fuel industry, the nuclear industry promotes itself as an essential source for battling climate change, yet advocates leave the discussion of nuclear waste behind closed doors and ignore each plant's potential devastative power.

It is during the process of a Nuclear Power Plant development, that today's architects face a dilemma. Should they play a

⁵ Cha, Ariana Eunjung. Up to 90 per cent of cancers due to lifestyle choices, environment, study says. www.news.nationalpost.com

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role in making these facilities look more palatable, or decline to get involved on ethical ground? Even for pro-nuclear architects, these are not the kind of projects that look good in the portfolio. But to avoid the issue could be self-defeating - effectively arguing that they should look ugly, because to make them look nice would be a tacit admission of approval. The other option would simply be to refrain from building new plants - yet it seems the model that is missing in most cases is the end-of-life model, where the reality of power plant decommissioning and site remediation can take decades to complete in order for the site to once again become usable.

In Canada, the debate over nuclear energy continues. As current refurbishment plans are underway for some of its nuclear facilities, many oppositional groups are trying to close its oldest nuclear reactor; the Pickering Nuclear Generating Station. With only a year left on its operating licence, this facility and site could offer new possibilities for the surrounding community and for the province of Ontario.

HISTORY OF NUCLEAR

The science behind atomic radiation and nuclear fission was developed from 1895 to 1945,⁶ the majority of it in the last six of those years, with the focus on the atomic bomb during the Second World War. Following 1945, attention was directed towards harnessing this energy in a controlled fashion; resulting in nuclear propulsion for submarines and power plants.

The Discovery of Fission

In 1934, physicist Enrico Fermi conducted experiments in Rome that showed the splitting of atoms* from the resultant collision with fired neutrons.⁷ When he experimented using uranium* atoms, however, the resulting elements were much lighter than uranium.

⁶ World Nuclear Association. Outline History of Nuclear Energy. March, 2014. www.world-nuclear.org

⁷ U.S. Department of Energy. The History of Nuclear Energy. www.energy.gov

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Further research in the fall of 1938 by German scientists Otto Hahn and Fritz Strassman revealed that when neutrons from a source containing the elements radium* and beryllium* were fired into uranium, the leftover materials contained lighter elements.⁸ These elements had about half the atomic mass of uranium, but when added together the masses did not total the uranium's mass. Lise Meitner, an Austrian colleague, would use Einstein's theory to show that the lost mass changed to energy, proving the occurrence of fission.⁹

Although they are tiny, atoms have a large amount of energy holding their nuclei together. Certain isotopes* of some elements can be split and will release part of their energy as heat. This splitting is called "fission". Uranium-235 (U-

8 U.S. Department of Energy. The History of Nuclear Energy. www.energy.gov

9 Ibid.

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²³⁵U) is one of the isotopes that fissions easily. During fission, U-235 atoms absorb loose neutrons. This causes U-235 to become unstable and split into two light atoms called “fission products”.

The combined mass of the “fission products” is less than that of the original U-235. The reduction occurs because some of the matter changes into energy; this energy is released as heat. Two or three neutrons are released along with the heat, which may hit other atoms, causing a series of fissions, known as a “chain reaction”. If enough uranium is brought together under the right conditions a continuous “chain reaction” occurs, called a “self-sustaining chain reaction”. This would become the process used in nuclear power plants.

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The Development of Nuclear Energy for Peaceful Applications

Early in 1942, a group of scientists led by Fermi gathered at the University of Chicago to begin construction on the world's first nuclear reactor, which became known as "Chicago Pile-1". The pile was built on the floor of a squash court beneath the University of Chicago's athletic stadium. On the morning of December 2nd, 1942, the scientists were ready to begin a demonstration of the reactor, and at 3:25 p.m., Chicago time, the nuclear reaction became self-sustaining.¹⁰ Fermi and his group had successfully transformed scientific theory into technological reality. The world had entered the nuclear age.

¹⁰ U.S. Department of Energy. The History of Nuclear Energy. www.energy.gov

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Following the War, a major goal of nuclear research in the mid-1950s was to show that nuclear energy could produce electricity for commercial use. The first commercial electricity-generating plant powered by nuclear energy was located in Shippingport, Pennsylvania. The “light-water” reactor, which uses ordinary water to cool the reactor core during the chain reaction, started first producing electricity on December 18th, 1957.¹¹

The nuclear power industry would continue to grow rapidly in the 1960s. Utility companies saw this new form of electricity production as economical, environmentally clean, and safe. In the 1970s and 1980s, however, growth slowed. Demand for electricity decreased and concern grew over

¹¹ The American Society of Mechanical Engineers. Shippingport Nuclear Power Station. www.asme.org

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nuclear issues, such as reactor safety, waste disposal, and other environmental considerations.

Nuclear Accidents

Serious nuclear accidents have been few and far between, each with a rating given by the International Atomic Energy Agency (IAEA) on the International Nuclear and Radiological Event Scale (INES)[Fig.1]. The three most known examples are the accidents at Three Mile Island, USA; Chernobyl, Ukraine; and Fukushima, Japan; receiving a 5, 7, and 7 respectively on INES.¹²



Fig. 1: International Nuclear and Radiological Event Scale(INES).

Growth or Decay

¹² International Atomic Energy Agency. "INES: The International Nuclear and Radiological Event Scale." www.iaea.org

Three Mile Island

On March 28th, 1979, the Three Mile Island Nuclear Generating Station[Fig.2], located in the Londonderry Township, Pennsylvania, USA, experienced a partial meltdown in its second reactor. The meltdown was attributed to a combination of equipment malfunctions, design-related problems and worker errors, which led to a release of radioactivity off-site.¹³ This was the most serious accident in U.S. commercial nuclear power plant operating history, causing US\$2.4 billion in property damages.¹⁴ Although these releases had no detectable health effects on plant workers or the public, its aftermath brought about



Fig. 2: Three Mile Island Nuclear Power Plant, Pennsylvania, USA.
Source: Atomic Archive.

¹³ U.S. Nuclear Regulatory Commission. "Backgrounder on the Three Mile Island Accident." www.nrc.gov

¹⁴ Sovacool, Benjamin K. Contesting the Future of Nuclear Power: a Critical Global Assessment of Atomic Energy. World Scientific. 2011. Pg. 75.

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sweeping changes involving emergency response planning, reactor operator training, human factors engineering, radiation protection, and many other areas of nuclear power plant operations.¹⁵ The decommissioning of the plant and restoration of the site are still decades away, as the plant still has an active reactor. The license for Unit 1 expires in 20 years, at which point both reactors will be dismantled together over a 10 year period; with plans calling for a full restoration of the site by 2054 -- 75 years after the accident.¹⁶

15 U.S. Nuclear Regulatory Commission. "Backgrounder on the Three Mile Island Accident." www.nrc.gov

16 Cusick, Marie. "Three Mile Island: 35 years later." *State Impact*. March 28, 2014. www.npr.org

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Chernobyl

The Chernobyl Nuclear Power Complex[Fig.3] is situated about 130 km north of Kiev Ukraine, and about 20 km south of the border with Belarus. The facility consisted of four Light Water Graphite-Moderated Reactors (RBMK) built between 1970 and 1983 and cooled by an artificial lake of some 22 square kilometers, which sits adjacent to the Pripyat River.

On the evening of April 25th, 1986, engineers inside the No.4 reactor experimented with the cooling pump system to see if it could still function without auxiliary electricity supplies. In order to proceed with the test, the operators turned off the automatic shutdown system. At the same time, they mistakenly lowered too many control rods into the reactor



Fig. 3: Chernobyl Nuclear Power Complex, Chernobyl, Ukraine. Source: Wired.

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core, dropping plant output too quickly. This stressed the fuel pellets, causing ruptures and explosions, bursting the reactor roof and sweeping the eruption outwards into the surrounding atmosphere. As air raced into the shattered reactor, it ignited flammable carbon monoxide gas and created a radioactive fire that burned for nine days and continued to release radiation for more than two weeks.¹⁷

The Chernobyl disaster was a unique event and the only accident in the history of commercial nuclear power where radiation related fatalities occurred.¹⁸ The meltdown distributed more than 200 times the radiation released by the atom bombs dropped on Hiroshima and Nagasaki,¹⁹ resulting

17 Sovacool, Benjamin K. Contesting the Future of Nuclear Power: a Critical Global Assessment of Atomic Energy. Pg.72.

18 World Nuclear Association. Chernobyl Accident 1986. April, 2016. www.world-nuclear.org

19 Sovacool, Benjamin K. Contesting the Future of Nuclear Power: a Critical Global Assessment of Atomic Energy. Pg.72.

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in the deaths of two plant workers the night of the accident, and a further 28 people dying of acute radiation poisoning within a few weeks.²⁰

The plant operators' town of Pripyat [45 000 residents] was evacuated two days after the meltdown, unaware of its severity; a few weeks later some 116 000 people that had been living within a 30-kilometre radius had been evacuated and later relocated.²¹ What is surprising is that even after the accident, the plant's remaining three reactors stayed active; Unit 2 shutting down in 1991 after a turbine hall fire; Unit 1 at the end of 1997 and Unit 3 shutting down in 2000.

Since its closure, the Ukraine government has announced a

²⁰ World Nuclear Association. Chernobyl Accident 1986. April, 2016. www.world-nuclear.org
²¹ Ibid.

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four-stage decommissioning plan which includes a confinement structure for Unit 4[Fig.4] and its existing concrete shelter. In February 2014, a new stage of the official plan was approved for units 1-3, involving the dismantling and safer storage of equipment by 2028; then, to 2046, where further equipment will be removed, and by 2064 the reactors will be demolished.²² The total cost of the new shelter was estimated to cost €1.5 billion in 2011.²³



Fig. 4: Chernobyl Arch under construction in 2014. Source: NY Times.

²² World Nuclear Association. Chernobyl Accident 1986. www.world-nuclear.org
²³ Ibid.

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Fukushima

On Friday March 11th, 2011, a magnitude 9 earthquake occurred off the East coast of Japan. Following the quake a 15 meter tsunami struck the Fukushima Daiichi Nuclear Power Plant[Fig.5], disabling the power supply and cooling of three reactors, causing a meltdown of all three cores in the first three days following the tsunami.²⁴ The accident was rated a 7 on the International Nuclear Event Scale (INES), matching Chernobyl with the highest achievable level, and deeming it a major accident.

Some 160 000 people within a 30 km radius of the site were evacuated in the weeks following the accident, as the evacuation zone continued to get larger from the original



Fig. 5: Fukushima Daiichi Nuclear Power Plant. Source: Daily Tech.

²⁴ World Nuclear Association. "Fukushima Accident". www.world-nuclear.org

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2km radius.²⁵ Although it lies outside the no-entry zone around the plant, Iitate Village, a farming village of 6,200 residents, located 30-40 km Northwest of the Fukushima Daiichi Nuclear Power Plant, had to be evacuated by the Japanese authorities due to extremely high radiation levels. Kenichi Hasegawa, a dairy farmer and leader of the Maeda District of Iitate Village, expressed his concern over nuclear energy following the incident:

"Until the accident, I never believed such a thing could happen. We were always told nuclear plants were safe. But nuclear plants are man-made, they cannot beat nature and are not unbreakable. Radiation is a terrible monster. Humans treated it

²⁵ World Nuclear Association. "Fukushima Accident". www.world-nuclear.org

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much too lightly. Chernobyl, Three Mile Island, Fukushima...We must prevent anyone else from suffering as we have."²⁶

Now, six years later, the cleanup is still nowhere nearer to completion, with projections of it taking up to 40 years according to the plant's operator at Tokyo Electric Power Company [TEPCO],²⁷ and current cost projections of upwards of \$250 billion[US].²⁸ The biggest obstacle to closing down the plant permanently is removing all the melted nuclear fuel debris from the reactors. High radiation levels within the facility still prevent workers from accessing the reactor buildings, and all attempts through robotic-based

²⁶ Vimeo. Hasegawa Kenichi - Fukushima Dairy Farmer. www.vimeo.com

²⁷ Wakatsuki, Yoko. Japan: Fukushima clean-up may take up to 40 years, plant's operator says. www.cnn.com

²⁸ GreenPeace. Don't Let General Electric Hitachi Toshiba Walk Away From the Fukushima Disaster! www.greenpeace.org

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removal have failed.²⁹

The Fukushima nuclear disaster provided yet another example to the international community that nuclear reactors are fundamentally dangerous. Not only do they cause significant damage to the environment, the health of populations and to national economies, the heavy financial cost of a meltdown is inevitably borne by the public. None of the world's nuclear reactors are immune to human errors, natural disasters, or any of the many other serious incidents that could cause a disaster. As these events in Japan continue to unfold, Nations around the world, including Canada, are faced with yet another reason to abandon their nuclear programs.

²⁹ Staedter, Tracy. Fukushima Robots Have Died from Radiation. Discovery News. March 11, 2016. www.news.discovery.com

NUCLEAR IN CANADA

For many years Canada has been a leader in nuclear research and technology, exporting their own reactor systems developed in Canada, as well as a high proportion of the world supply of radioisotopes used in medical diagnosis and cancer therapy.³⁰ Research into nuclear power reactors began in 1944, when an engineering design team was brought together in Montreal, Quebec, to develop a heavy water moderated nuclear reactor.³¹

Three years later, the National Research Experimental Reactor (NRX) began operation in 1947 at Chalk River, Ontario, where today the Chalk River Laboratories (CRL) are the locus of much of Canada's nuclear research and development. In 1952, the government established Atomic Energy of Canada Ltd (AECL) to mandate the research and development of nuclear energy for peaceful use. What is little known, however, is that in the same year, the NRX would endure a major nuclear accident; the first in nuclear reactor history.³²

³⁰ World Nuclear Association. Nuclear Power in Canada. www.world-nuclear.org

³¹ Edwards, Gordon. Reactor Accidents at Chalk River: The Human Fallout. www.ccnr.org

³² Ibid.

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The NRX reactor underwent a violent power excursion that destroyed the core of the reactor, resulting in the melting of some uranium fuel. Concurrently, the shut-off rods failed to fully descend into the core, causing a series of hydrogen gas explosions which hurled the four-ton gasholder dome four feet through the air where it jammed in the superstructure. Thousands of curies* of fission products were released into the atmosphere, and a million gallons of radioactively contaminated water had to be pumped out of the facility's basement to be "disposed of" in adjacent shallow trenches, situated not far from the Ottawa River.³³ The NRX reactor core could not be salvaged, and would have to be buried as radioactive

33 Edwards, Gordon. Reactor Accidents at Chalk River: The Human Fallout. www.ccnr.org

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waste. The accident was so serious that it required a joint cleanup by both Canadian and American servicemen; young Jimmy Carter – later U.S. President, then a nuclear engineer in the U.S. Navy—was among the hundreds who were ordered to participate in the cleanup.³⁴

The accident was a severe but temporary setback to research reactor operation which prompted quick reaction, limiting its effect on personnel and the environment. Repairs were quickly made and the NRX was back in operation on February 16th, 1954, and by early April it was at a new operating power of 40 MW.³⁵

Following the NRX, plans were made for a heavy water

34 Edwards, Gordon. Reactor Accidents at Chalk River: The Human Fallout. Canadian Coalition for Nuclear Responsibility. www.ccnr.org
35 Hurst, D.G.. Canada Enters the Nuclear Age: A Technical history of Atomic Energy of Canada Limited as Seen from Its Research Laboratories. Pg. 50.

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reactor, and in 1957 The National Research Universal (NRU) reactor was built at Chalk River. The reactor had a power rating five times that of the NRX, with 200 MW; the effective core size was also 40 percent larger in volume than the NRX.³⁶ In the early operation of the NRU, however, fuel failures were a major problem. In May 1958, during the removal of a failed fuel rod, a piece of uranium fell out of the removal flask into a pit at the top of the reactor, and caught fire, spreading deadly fission products and alpha-emitting particles throughout the reactor building. The building was severely contaminated and it was three months before the reactor could be started again.³⁷

³⁶ Hurst, D.G.. Canada Enters the Nuclear Age: A Technical history of Atomic Energy of Canada Limited as Seen from Its Research Laboratories. Pg. 53.
³⁷ Ibid. Pg. 54.

nuclear in Canada

Today, after decades of research and development, the CANDU reactors began operations in Pickering, Ontario, in NRU produces 40% of the world supply of molybdenum-1971. Since then Canada has exported CANDU reactors to 99, the source of technetium-99 widely used for medical Argentina, China, India, Pakistan, Romania, and South diagnosis, and cobalt-60 for cancer treatment.³⁸ It is due Korea, with 31 CANDU reactors in operation to be shut down in March 2018, after six decades of globally³⁹[Fig.7]. service.

The AECL, in cooperation with Canadian Industry, began developing the first CANDU (CANadian Deuterium Uranium)[Fig.6] reactor in the late 1950s following the NRU. They use heavy water (deuterium oxide) as a moderator and coolant, and are fueled using natural uranium – through the 1960s, until the first commercial

38 World Nuclear Association. Nuclear Power in Canada. www.world-nuclear.org

39 Canadian Nuclear Association. CANDU TECHNOLOGY. www.cna.ca

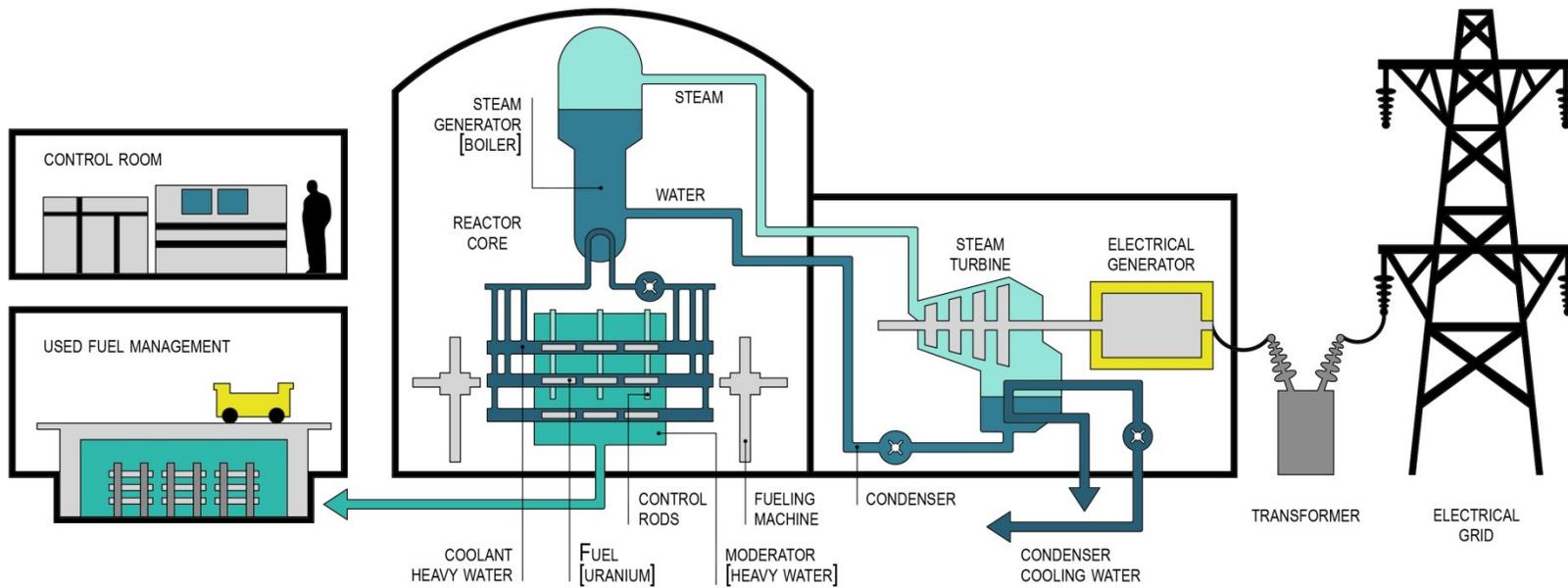


Fig. 6: CANDU Reactor System. Based from CNA diagram.

| CANDU reactors in operation around the world | | | |
|--|-----------------|-------|--------------------|
| Country | Type of reactor | Units | Net capacity (MWe) |
| Argentina | CANDU | 1 | 600 |
| Canada | CANDU | 19 | 13,513 |
| China | CANDU | 2 | 1,280 |
| India | CANDU | 2 | 277 |
| Pakistan | CANDU | 1 | 125 |
| Romania | CANDU | 2 | 1,305 |
| South Korea | CANDU | 4 | 2,579 |

Fig. 7: CANDU reactors in operation around the world. Data from CNA.

nuclear in Canada

Today, Canada remains one of the top nuclear energy producing countries in the world[Fig.8], with four plants producing about 15 percent of Canada's electricity⁴⁰

[Fig.9]:

- o Bruce Nuclear Generating Station, Ontario
- o Pickering Nuclear Generating Station, Ontario
- o Darlington Nuclear Generating Station, Ontario
- o Point Lepreau Generating Station, New Brunswick

Until recently, Canada had five operating plants in the country, with the closure of Quebec's Gentilly-2 Nuclear Plant in 2012. The plant's closure is expected to cost \$1.8 billion over a period of more than 50 years; with the plant

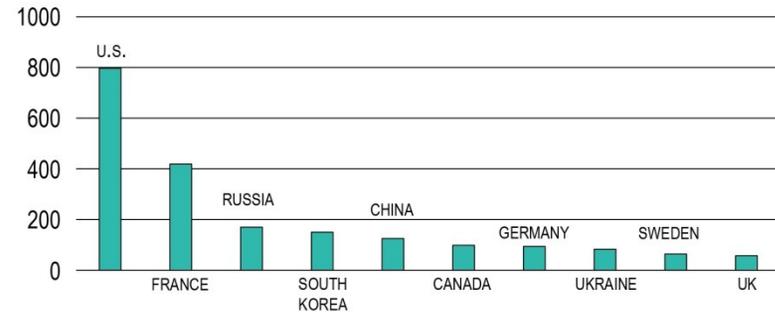


Fig. 8: Top 10 Nuclear Generating Countries (Billion kWh, 2014). Data from WNA.

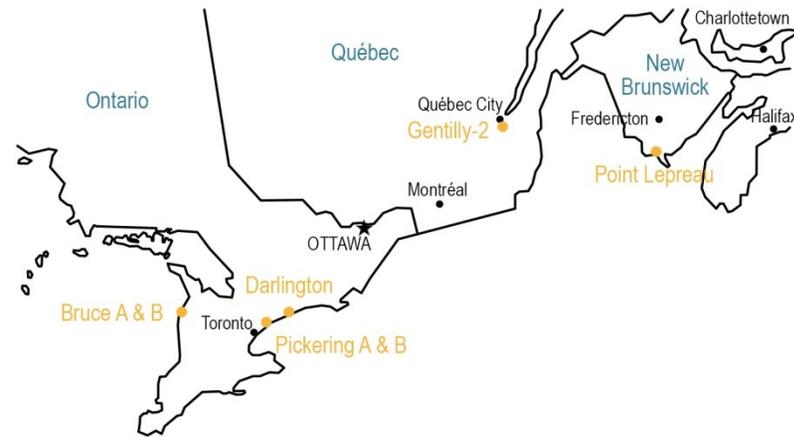


Fig. 9: Nuclear Plants in Canada.

⁴⁰ Canadian Nuclear Safety Commission. Nuclear Power Plants. www.cnsccsn.gc.ca

nuclear in Canada

undergoing a “sleeping” stage, where it will remain idle until 2062, when used fuel rods can be removed from the site and the plant can be completely taken apart.⁴¹

The next facility slated for closure is the Pickering Nuclear Generating Station[Fig.10], located on the shores of Lake Ontario, just east of Toronto. This facility is one the world's largest and oldest nuclear generating plants at 45 years old. The plant's license has already been extended previously until 2018, but OPG is seeking another license extension which would keep the plant running until 2024 to allow for the refurbishment of the Darlington Nuclear Generating Station[Fig.11]; a facility which was also originally scheduled to be

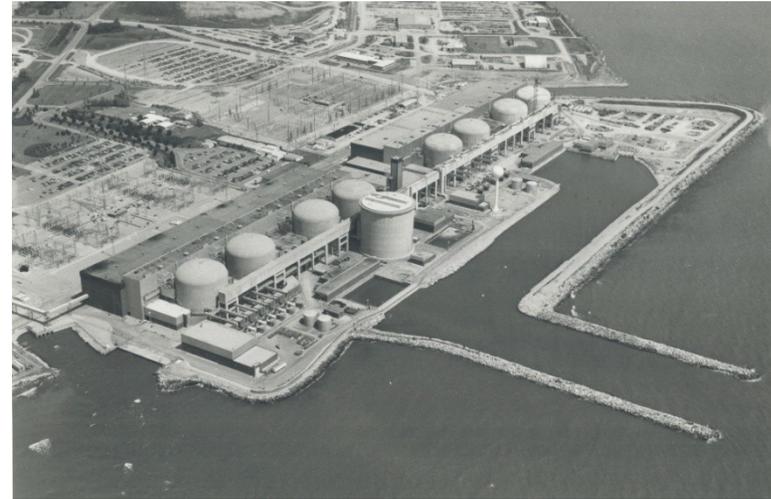


Fig. 10: The Pickering Nuclear Generating Station. Source: Virtual Reference Library.

41 CBC News. Quebec's Gentilly-2 nuclear plant shuts down after 29 years. www.cbc.ca

nuclear in Canada

decommissioned in 2020. The refurbishment began in the fall of 2016 and is expected to cost \$12.8 billion, extending the lifespan of the facility a further three decades.⁴²

Following the Fukushima accident, many countries have largely stopped building new nuclear plants, with countries like Germany choosing to phase-out the industry completely by 2022.⁴³ However, with a chance to decrease the country's reliance on nuclear energy, Canada's government decided to allow the extension of their program instead; allowing the continued potential for disaster to occur at its facilities.



Fig. 11: The Darlington Nuclear Generating Station. Source: Ecocide Alert.

42 Ontario Power Generation. Darlington Refurbishment. www.opg.com
43 BBC. Germany: Nuclear power plants to close by 2022. www.bbc.com

PICKERING NUCLEAR GENERATING STATION



Growth or Decay

Fig. 12: The Pickering Nuclear Generating Station.
Source: Canadian Underwriter.

pickering nuclear generating station

Located on the shores of Lake Ontario just east of Toronto, and settled into the city of Pickering, is one of the world's oldest and largest nuclear generating facilities: The Pickering Nuclear Generating Station[Fig.12]. The facility has six operating CANDU reactors with a total output of 3100 megawatts, enough to serve a city of one and a half million people and about 14 percent of Ontario's electricity needs.⁴⁴ The original design of Pickering included four Pressurized Heavy Water Reactors (PHWR), built between 1971 – 1973. Ten years later, four more reactors would be built between 1983 – 1986; the two sets of reactors became Pickering A and B[Fig.13]. The facility has not been without its problems

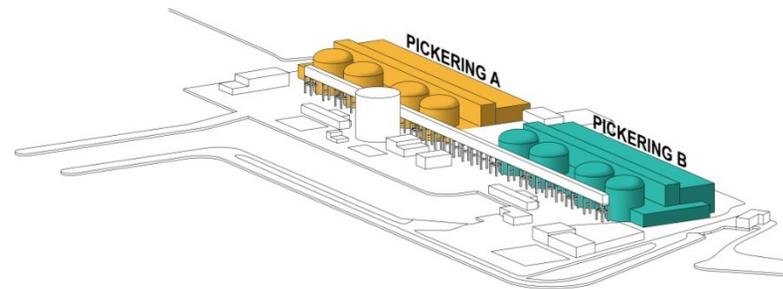


Fig. 13: Pickering A & B Stations.

⁴⁴ Ontario Power Generation. Pickering Nuclear. www.opg.com

Pickering nuclear generating station

however, with multiple accidents and releases to the environment over its operational lifetime.

| | |
|--------------------|---|
| August 1, 1983 | Pickering reactor 2 had a 'loss of coolant accident' (LOCA), after a pressure tube suffered a metre-long rupture. The entire station was shut down. The four reactors at Pickering "A" were eventually retubed at a cost of about \$1 billion -- more than the original \$716 million cost of the station. |
| November 22, 1988 | Pickering reactor 1 had a power excursion caused by operator error that caused damage to 36 fuel bundles. The cooling system was contaminated by radioactive iodine, which was vented over several weeks following the accident. Ontario Hydro did not believe that such an accident was possible, and had to revise its operating procedures and retrain staff. |
| September 25, 1990 | Pickering reactor 2 had a "severe flux tilt", with large power shifts in the reactor core, caused in part by the CANDU design. Staff spent two days trying to stabilize the reactor core before shutting it down, and were later criticized by the AECB for not shutting it down immediately. |
| August 2, 1992 | Pickering reactor 1 had a heavy water leak from a heat exchanger that resulted in a release of 2,300 trillion becquerels* of radioactive tritium into Lake Ontario. This was the worst-ever tritium release from a CANDU reactor, and resulted in increased levels of tritium in drinking water from Whitby to Burlington. |
| December 10, 1994 | Pickering reactor 2 had a major 'loss of coolant accident' (LOCA). A pipe break resulted in a spill of 185 tonnes of heavy water. For the first time ever, at a CANDU, the Emergency Core Cooling System (ECCS) was used to prevent a meltdown, and about 200 workers were involved in the clean-up. The reactor was restarted on February 14, 1996. |
| July 21, 1995 | Two technicians carried out work on the wrong reactor (Pickering reactor 5 instead of reactor 6), disabling the second fast shutdown system on reactor 5, which was operating at full power at the time. |
| February 19, 1996 | About 500 tonnes of water spilled into the #6 reactor building when employees working on an Emergency Water Supply valve failed to isolate it from the system. An investigation revealed that safety equipment could have failed due to water damage, and both the primary and backup heat sinks were actually lost for a section of the reactor core. The accident blew a 60 lb. valve component 6 feet into the air, almost hitting |

pickering nuclear generating station

| | |
|------------------|---|
| | a worker and shot water up to the reactor building dome. |
| April 21, 1996 | All eight reactors at the Pickering nuclear stations were shut down to repair a backup valve on the Emergency Core Cooling System. The flaw was detected on April 15th, and the system had been tested one month earlier. Hydro did not advise the public of this situation until April 20th. |
| October 11, 1996 | "Drug paraphernalia" were found in the 'Operating Island' at the Pickering nuclear stations. A station manager commented: "The continuing discovery of such items in the plant is both embarrassing and a threat to our recovery and survival as a business." This was one of five significant event reports relating to illicit alcohol and/or drug use in the Pickering nuclear stations in 1996. |
| May 17, 1997 | A media report revealed that Ontario Hydro had failed to report the dumping of more than 1,000 tonnes of copper, zinc and other metals into Lake Ontario from the Pickering stations, due to the erosion and corrosion of brass steam condensers. DNA has requested an investigation under the Environmental Bill of Rights, alleging that Ontario Hydro officials knowingly reported incomplete environmental data to the Province of Ontario. |
| July 30, 1997 | Ontario Hydro revealed that it had failed to report tritium contamination of ground water at the Pickering nuclear generating station for the last twenty years. In 1979 it found 2,150,000 becquerels per litre (Bq/L) of tritium in ground water, and in 1994 found 700,000 Bq/L. |

[Source: Canadian Coalition for Nuclear Responsibility. *Seven Ontario Hydro CANDU Reactors to Shut Down*. www.ccnr.org]

pickering nuclear generating station

In 1997, Ontario Hydro, the forerunner to Ontario Power Generation (OPG), shut down seven of the eight Pickering reactors at an estimated cost of \$5 billion - \$8 billion.⁴⁵

45 The Standing Senate Committee on Energy, the Environment, and Natural Resources. *Canada's Nuclear Reactors: How Much Safety is Enough?* www.sencanada.ca

Pickering nuclear generating station

The facility had been performing at a minimally acceptable level; according to Ontario Hydro's chief executive officer at the time, management had lost its focus on safety and efficiency, and allowed a deterioration of standards.⁴⁶

The Atomic Energy Control Board (AECB), the predecessor to the Canadian Nuclear Safety Commission (CNSC), had ordered Ontario Hydro to make key safety improvements at Pickering Nuclear Generating Station A by the end of 1997. Unable to meet the deadline, Ontario Hydro placed Pickering A under temporary shut down on December 31, 1997. The facility required an extensive refurbishment, and in August 1999, OPG approved

46 The Standing Senate Committee on Energy, the Environment, and Natural Resources. Canada's Nuclear Reactors: How Much Safety is Enough? www.sencanada.ca

Pickering nuclear generating station

restarting all four units at a cost of \$1.1 billion: \$457 million for Unit 4 and systems common to all four units, \$213 million for Unit 1, \$219 million for Unit 2, and \$211 million for Unit 3.⁴⁷ The plant restart was a major design and construction project, with modifications required to virtually all systems in the plant. It was not until September 2003 that Pickering A4 was brought back online, however, the project's cost was triple the original budget (\$1.25 billion) and was completed two years behind schedule.⁴⁸

In the wake of A4's restart, the government at the time, led by Mike Harris, commissioned a study to determine the causes of its cost overruns, however, by the time the

47 Bratt, Duane. Canada, the Provinces, and the Global Nuclear Revival: Advocacy Coalitions In Action. Pg..127.

48 Ibid.

Pickering nuclear generating station

review was released, on November 30th, 2003, there was a new provincial government. The newly elected Liberal government of Dalton McGuinty decided to commission a second study to determine whether or not to finish the Pickering A restart project.

In March 2004, the OPG Review Committee released its report, recommending that Pickering A1 be restarted with an additional investment of \$500 million. If A1's restart was successful without complications, then A2 and A3 could follow suit.⁴⁹ The Ontario government accepted the recommendation of the committee and in July 2004 announced that it would restart Pickering A1; it was restored to service in November 2005 and was completed

49 Bratt, Duane. Canada, the Provinces, and the Global Nuclear Revival: Advocacy Coalitions In Action. Pg..127.

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on time and on budget.

It was during A1's restart, OPG announced on August 12th, 2005 that it would retire Pickering A2 and A3 rather than attempt to restart them. President and CEO Jim Hankinson stressed that their restart was unnecessary, and that instead, OPG would focus on maximizing the electricity output of the restarted Pickering A4 and A1 units, refurbish Pickering B, and build new reactors at Darlington's Nuclear facility.⁵⁰

Following the restarts of A4 and A1, The Pickering Nuclear facility would continue to experience multiple accidents; several listed here:

50 Bratt, Duane. Canada, the Provinces, and the Global Nuclear Revival: Advocacy Coalitions In Action. Pg.129.

pickering nuclear generating station

| | |
|--------------------|--|
| March 7, 2011 | OPG staff discovered a failing pump seal had begun releasing moderator water containing tritium in the Unit 4 moderator room. |
| March 14, 2011 | A pump seal failure at the Pickering Nuclear A station released an estimated 73,000 litres of demineralised water containing trace amounts of tritium into Lake Ontario. |
| March 25, 2011 | Pickering Nuclear experienced a brief partial loss of power on its Unit 1 reactor, while performing start up activities. |
| June 5, 2012 | A number of condenser cleaning balls were inadvertently discharged into Lake Ontario from the Pickering Nuclear station. |
| July 5, 2012 | Between June 30 and July 5, Pickering Nuclear had a release of approximately 90 litres of oil to Lake Ontario. The release occurred over a period of six days from cooling equipment that is part of the non-nuclear systems. |
| August 17, 2012 | Between August 16 and 17, Pickering Nuclear had a release of up to 150 litres of oil into Lake Ontario. The release occurred overnight from equipment that is part of the non-nuclear systems. |
| October 11, 2012 | Pickering Nuclear had a spill of approximately 400 litres of moderator water within the station and an OPG employee was exposed to radiation. |
| January 2, 2013 | On the night of January 1, 2013, a fire broke out in a lube oil purification system in the Pickering Nuclear Unit 1 turbine hall. The station's automatic sprinkler system was activated and the fire was extinguished by Pickering Nuclear fire protection personnel. |
| January 14, 2014 | Approximately 200kg of heavy water was released onto the floor of the Unit 4 reactor building at the Pickering station during the transfer of liquid between two tanks. |
| April 29, 2014 | Operators at the Pickering station made the conservative decision to shut down the reactor in order to investigate the cause of instrumentation fluctuations for reactor moderator system on Unit 1. |
| August 15, 2014 | During routine equipment testing at the Pickering station, approximately 450 litres of fire retardant fluid was spilled inside the turbine hall. Almost all of the fluid was contained and collected, however, a trace amount had made its way to a drainage sump which empties into Lake Ontario. |
| September 11, 2014 | Pickering Nuclear received an equipment signal indicating the failure of sump pumps in the site |

pickering nuclear generating station

| | |
|--------------------|---|
| | sewage system. Staff attempted to restore the pumps, but the sumps overflowed resulting in the flow of sewage into an inactive drain which leads into Lake Ontario. It is estimated approximately 200 kgs of sewage may have been discharged into the Lake. |
| September 16, 2015 | Pickering Nuclear Unit 4 experienced a forced outage after a failure in the turbine governor valve trip circuit. The system trip left the province scrambling to import replacement power, as a number of the province's other reactors were also shutdown at the time for repairs. |

[Source: Ontario Power Generation. *Special Interest Station Updates*. www.opg.com]

pickering nuclear generating station

OPG has been promising the closure of the Pickering plant for a decade. First in 2007, then in 2013, and then in 2018. Now news has reached the public that it will seek yet another licence extension; news which does not sit well with local residents.

OPG has begun the work required to renew the operating licence for the Pickering Nuclear Generating Station, a process which is expected to be completed

pickering nuclear generating station

by August 2018. In May 2016, OPG informed the CNSC of its intent to request a ten year licence extension for the station's current operating licence. This licence term would cover the period between September 1, 2018 and August 31, 2028. The current plan is to operate all six units until 2022 at which time two units will be shut down, followed by the shutdown of the remaining four units in 2024. The remaining four years of the licence extension between 2024 and 2028 will allow for safe storage activities.⁵¹

51 Ontario Power Generation. Pickering Nuclear Licence Renewal. www.opg.com

TO CLOSE, OR NOT TO CLOSE?

The nuclear industry in Canada has long had its opposition; with groups like the Canadian Environmental Law Association (CELA), Durham Nuclear Awareness (DNA), Greenpeace, and the Ontario Clean Air Alliance (OCAA), among others, who have voiced their disapproval of the industry over the years.

With the impending licence expiration of the Pickering nuclear station in 2018, there is currently a debate over the possible licence extension of the plant till 2024. The Power Workers' Union and the OCAA have been especially vocal in their attempts to relay important information to the general public as for and against the extension respectively.

In 2016 Jack Gibbons (chair of OCAA) and the OCAA commissioned Torrie Smith Associates, an independent consulting firm, to look at the economic implications of decommissioning the Pickering Nuclear Station. The analysis revealed that there are major advantages to proceeding with decommissioning work immediately rather than following OPG's proposed approach of leaving the plant dormant for 30 years before proceeding.

to close, or not to close?

The first advantage is cost and cost certainty. Torrie Smith calculated that direct decommissioning can save \$800 million to \$1.2 billion on the total cost of decommissioning, in part by avoiding the costs of securing and maintaining the site for 30 years.⁵² This would also ensure that the financial risk for a first-of-its-kind project is not pushed forward 30 years, but dealt with today.

The second advantage is a smooth transition from an operating facility to a decommissioning project. This would help to ensure continued employment for many Pickering workers and would also ensure that existing expertise and plant-specific knowledge was readily

⁵² Ontario Clean Air Alliance. Direct Decommissioning of the Pickering Nuclear Generation Station: Economic and Other Benefits. www.cleanairalliance.org

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available to assist with the decommissioning process.⁵³

Under current licence, when the facility would be decommissioned thirty years from now, there will be few, if any workforce left with firsthand experience of Pickering's difficult operating history. Essentially, a whole new set of workers would have to be trained to undertake work on a plant with which they have no familiarity.

The third advantage is safety. There is no particular reason – other than relying on investment growth to increase decommissioning funds – to wait 30 years to begin the work.⁵⁴ The most radioactive component of the site – spent fuel and heavy water used for cooling – will

53 Ontario Clean Air Alliance. Direct Decommissioning of the Pickering Nuclear Generation Station: Economic and Other Benefits. www.cleanairalliance.org
54 Ibid.

to close, or not to close?

have to be removed immediately following shutdown, therefore, waiting 30 years to begin decommissioning would only allow for corrosion and decay to take a further toll on the plant, thereby increasing safety risks.

All of this makes direct decommissioning the logical way to proceed. Torrie Smith calculated that direct decommissioning will create 16,000 person years of employment, which is greater than the 15,400 person years of employment that OPG estimates would be created by its proposed Darlington re-build project.⁵⁵ But just as importantly, the funds to decommission Pickering will come from a dedicated Decommissioning Fund whereas the funds for the Darlington Re-build will come from

55 Ontario Clean Air Alliance. Direct Decommissioning of the Pickering Nuclear Generation Station: Economic and Other Benefits. www.cleanairalliance.org

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electricity consumers, meaning the Pickering project will have no impact on electricity rates while the Darlington project will increase rates.⁵⁶

Contrary to the Torrie Smith analysis, Don MacKinnon (President of the Power Workers' Union) and the PWU commissioned their own report on the benefits of running Pickering till 2024, in an analysis by Strategic Policy Economics (Strapolec) in 2016. In the December 2016 issue of the Toronto Star, the PWU published their highlights of the report, in an ad presenting material advocating for Ontario's commitment to nuclear energy, under the title of "Ontario's Commitment to Nuclear is Good News For Jobs and Greenhouse Gas Reductions".

⁵⁶ Ontario Clean Air Alliance. Direct Decommissioning of the Pickering Nuclear Generation Station: Economic and Other Benefits. www.cleanairalliance.org

to close, or not to close?

In the report, Strapolec confirmed that each year the Pickering station's output helps avoid millions of tonnes of GHG emissions while annually contributing hundreds of millions of dollars to the economies of Durham Region and Ontario. As well, extending the station's operations by just four years reduces electricity system costs by over \$600 million, saves \$4 billion from avoided energy imports and provides over \$1.2 billion in additional revenues to the provincial government.⁵⁷

Strapolec found that each year, the province's three nuclear stations have helped avoid tens of thousands of tonnes of smog producing pollutants and about 60 million

57 Toronto Star. Ontario's Commitment To Nuclear Is Good News For Jobs and Greenhouse Gas Reductions. December 3, 2016.

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tonnes of GHG emissions, "the equivalent of taking 12 million vehicles off the road",⁵⁸ yet they do not account for the millions of kilometers in travel from the transport of radioactive material from these plants.

One important point that the report highlighted was the size of the nuclear industry in Canada. Nuclear energy is a major contributor to the province's economy and Ontario is the heart of Canada's \$6 billion plus, 60,000 job nuclear industry; this includes 180 supply chain companies located in communities across the province and support for high-tech innovation-focused research and development at Ontario's universities and colleges.⁵⁹ The report also showed that extending the operation of the

58 Toronto Star. Ontario's Commitment To Nuclear Is Good News For Jobs and Greenhouse Gas Reductions. December 3, 2016.

59 Ibid.

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Pickering Station and the mid-life refurbishments of the Darlington and Bruce stations will generate billions in GDP and thousands of good jobs.⁶⁰

In the last paragraph, MacKinnon concludes by saying “Nuclear energy has, and will continue to be a major provider of reliable, low-carbon, low-cost electricity for decades to come”; a closer look into the realities of this statement will reveal otherwise.

'Reliable'

One of the main selling points of nuclear over other renewable energy sources is its ability for a constant flow of energy, whereas solar and wind are only effective when

60 Toronto Star. Ontario's Commitment To Nuclear Is Good News For Jobs and Greenhouse Gas Reductions. December 3, 2016.

to close, or not to close?

the sun is shining and the wind is blowing. However, with the constant flow of electricity comes the constant flow of radioactive releases from power plants. As seen in Fig.14, these releases corrupt the surrounding environment, and are inevitably absorbed by the populace through direct irradiation, exposure, or ingestion. CANDU reactors are especially inadequate in their design to cope with these releases. In fact they emit much more tritium than other reactor types[Fig.15], about 30 times more than the next most common reactor type.

In a recorded session with the OCAA, Dr. Ian Fairlie (PHD in Radioactive Waste Management from the Imperial College of London) addressed his concerns over tritium and Ontario's nuclear stations:

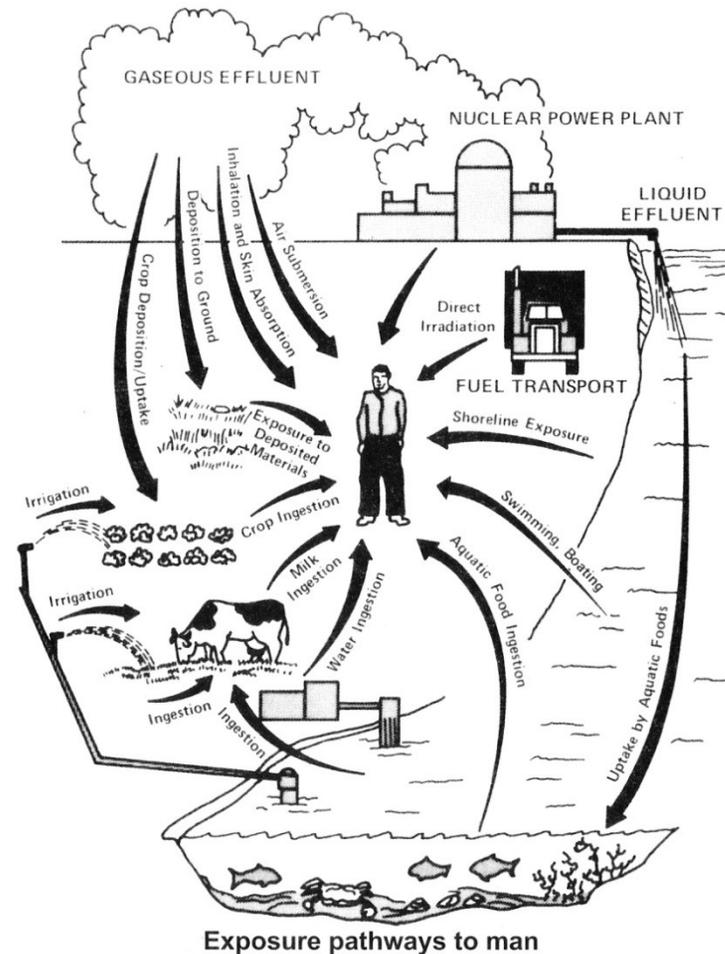


Fig. 14: Routine radioactive releases from nuclear power plants. Source: Beyond Nuclear

to close, or not to close?

“Tritium is the radioactive isotope of hydrogen. It has a half-life of 12.3 years, which means that it hangs about in the environment for a long period of time. When it gets inside your body, it sticks to your fats, to your proteins, to your carbohydrates for years, and it gives you high doses of radiation. Unfortunately these doses aren’t really taken into account by the authorities here in Canada, but they result in high levels of leukemias and birth defects in people that live nearby in both Pickering and Darlington.”⁶¹

Ontario’s nuclear plants are the country’s largest source of

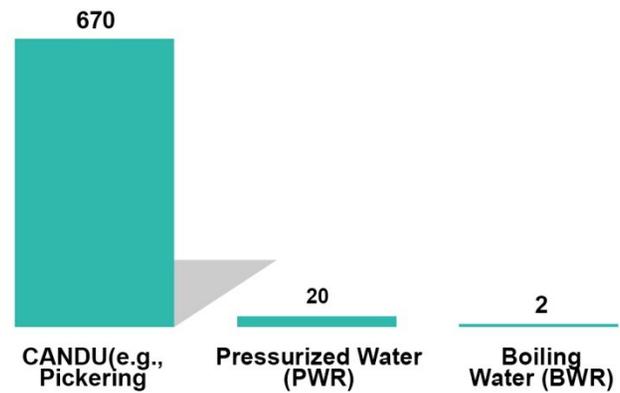


Fig. 15: Annual tritium releases by reactor types (Terabecquerels per Gigawatt). Data from OCAA.

61 Youtube. Dr. Ian Fairlie on Pickering’s Tritium Problem. www.youtube.com

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dangerous tritium emissions. This radioactive isotope is produced and released to the atmosphere constantly by CANDU nuclear reactors. Once tritium is inside us, because we breathe it in, absorb it through skin or consume contaminated food or water, it releases radioactivity in our bodies. Tritium is a carcinogen (causes cancer), teratogen (causes deformations of the embryo during pregnancy) and mutagen (causes mutations to DNA). Even very low rates of tritium exposure can lead to cancer, leukemia, and birth defects.⁶²

Dr. Fairlie would continue on to highlight a key component in the debate to close Pickering, “The tritium discharges (at Pickering and Darlington Nuclear stations)

62 Ontario Clean Air Alliance. Ontario nuclear’s tritium problem. www.cleanairalliance.org

to close, or not to close?

are the highest in the world, from any nuclear facility, and this is really serious because there are very large populations near both of the power stations. Altogether about 6 million people live within 50 km of the two power stations. ”⁶³

A closer look into the Pickering Nuclear Station reveals that it is surrounded by more people than any other nuclear station in North America. Specifically, 2.2 million people live within 30 kilometres of the Station [Fig.16].⁶⁴

At half the surrounding population, the Indian Point Nuclear Station, which is located north of New York City,

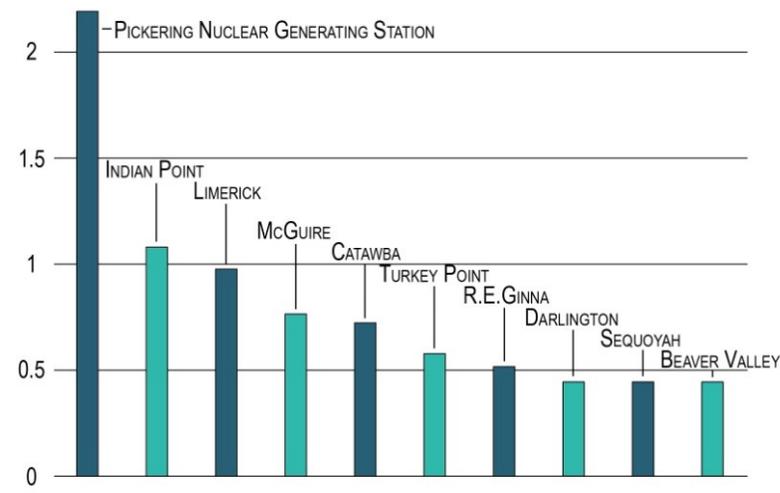


Fig. 16: 10 North American nuclear plants with the highest Surrounding populations(in millions within 30km). Data from OCAA.

Growth or Decay

63 Youtube. Dr. Ian Fairlie on Pickering's Tritium Problem. Ontario Clean Air Alliance. www.youtube.com
64 Ontario Clean Air Alliance. Closing the Pickering Nuclear Station in 2018. www.cleanairalliance.org

to close, or not to close?

sits second on the list with 1.1 million people. New York Governor Andrew Cuomo has been seeking the closure of the plant for 15 years. In January of 2017, Mr. Cuomo announced that the state had reached an agreement with the plant's operator, Entergy, to shut it down by April 2021. He added that the proposed closing "eliminates a major risk, provides welcome relief, and New Yorkers can sleep a little better."⁶⁵

If a meltdown event, like Fukushima or Chernobyl, were to occur at the Pickering plant, there would not be a way to accommodate the 2.2 million people that live within the 30 km radius of the plant. As seen in Fig.17, much of Toronto falls within this zone, but what is more

65 McGeehan, Patrick. Cuomo Confirms Deal to Close Indian Point Nuclear Plant. www.nytimes.com

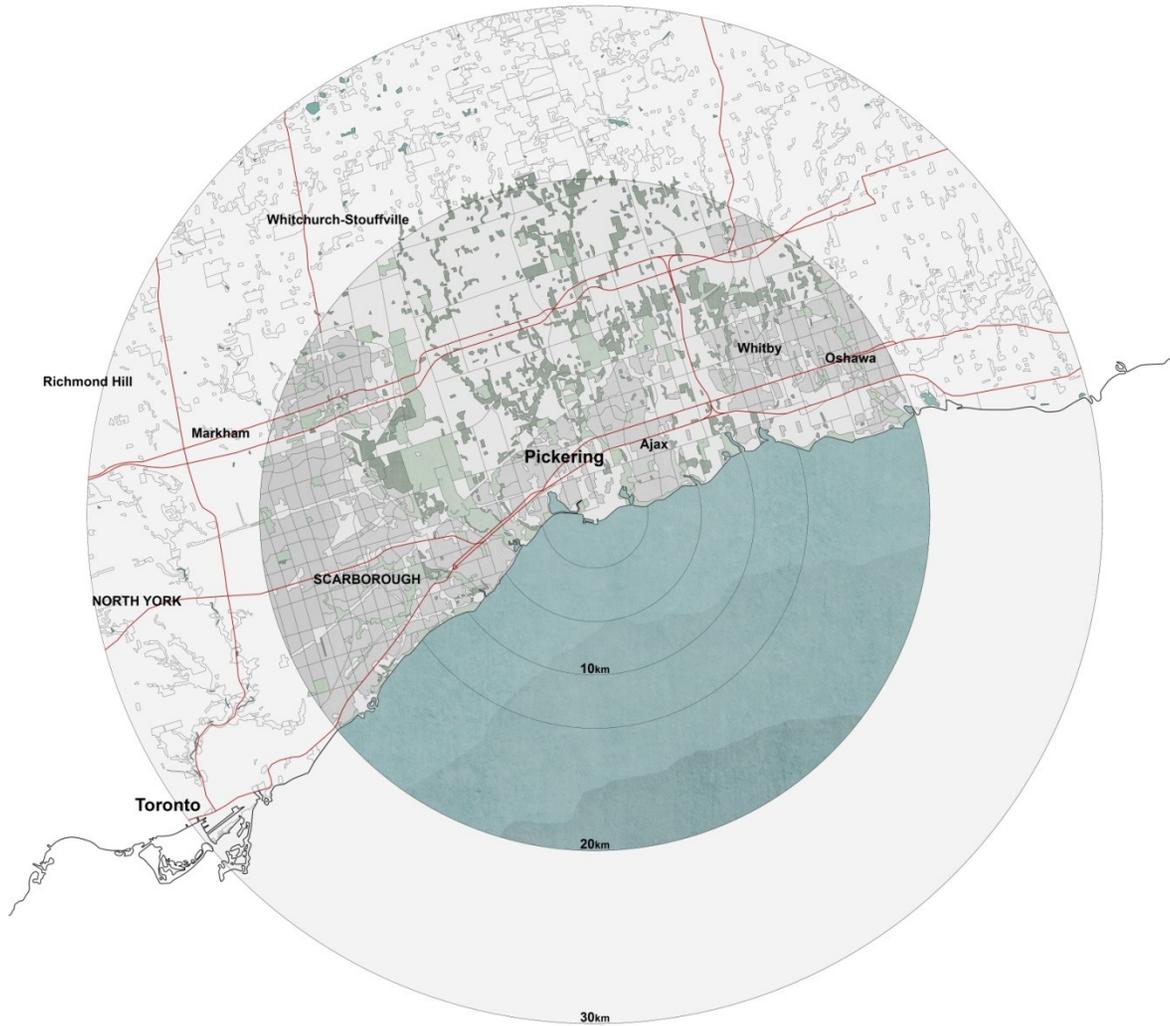


Fig.17: 30km surrounding the Pickering Nuclear Plant.

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concerning is the fact that it is only a fraction of the 9 million people living in both Ontario, Canada and New York State, USA that rely on Lake Ontario for drinking water.

Each year, results from OPG's Environmental Monitoring Program (EMP) are analyzed to determine any environmental impacts from its nuclear generating stations. The 2015 EMP report concluded that Pickering's estimate annual public dose was 1.2 *microsieverts;⁶⁶ a fraction of the annual regulatory limit of 1,000 microsieverts, set by the CNSC.

Although the reported amounts are 'minimal', releases will vary, and what remains is the reality that these reported annual amounts are indeed "estimates".

The past large releases of tritium, as well as current routine releases are unnerving to the public who may or may not in fact be aware of the situation. In the search for a 'reliable' means of electricity production, what holds true is that to rely on nuclear energy is indeed dangerous.

66 Ontario Power Generation. Neighbours Newsletter: Annual Environmental Monitoring Results. Fall 2016.

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'Low-Carbon'

Nuclear advocates often attribute their energy production with low GHG emissions, which is true in terms of the releases from nuclear facilities. However, as an entire industry, the nuclear sector is far from low in their emissions, with the majority of GHGs coming from the transport of radioactive material to storage and entombment. Yet, what may be seen as more damaging are the environmental impacts of uranium mining and milling. These impacts can be quite severe, ranging from the creation of massive stockpiles of radioactive and toxic waste rock and sand-like tailings to serious contamination of surface and groundwaters with

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radioactive and toxic pollutants.⁶⁷ In fact, the impacts of uranium mining have been so severe, that many jurisdictions around the world have adopted bans on the establishment of new uranium mines.

What is unknown to many is that until 2009 Canada was the world's largest uranium producer, accounting for about 22% of the world output, before it was overtaken by Kazakhstan in 2009⁶⁸ [Fig.18]. Currently, there are five active uranium mines, all located in Saskatchewan, with the majority of the uranium production coming from the McArthur River and Cigar Lake mines in northern Saskatchewan. In 2016 alone, Canada's mines had a

| Country | 2011 | 2012 | 2013 | 2014 | 2015 |
|------------|--------|--------|--------|--------|--------|
| Kazakhstan | 19 451 | 21 317 | 22 451 | 23 127 | 23 800 |
| Canada | 9 145 | 8 999 | 9 331 | 9 134 | 13 325 |
| Australia | 5 983 | 6 991 | 6 350 | 5 001 | 5 654 |
| Niger | 4 351 | 4 667 | 4 518 | 4 057 | 4 116 |
| Russia | 2 993 | 2 872 | 3 135 | 2 990 | 3 055 |

Fig.18: Production of uranium from the top 5 countries(in tonnes) 2011 - 2015. Data from WNA.

67 Pembina Institute. Uranium Mining: Nuclear Power's Dirty Secret. www.pembina.org
68 World Nuclear Association. Uranium in Canada. www.world-nuclear.org

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combined output of 16 541 tonnes of uranium, and with known uranium resources of 582 500 tonnes,⁶⁹ it will play a significant role in meeting future world demand.

Supplying a typical Canadian household with nuclear-generated electricity results in the production of 14kg of toxic and radioactive mine tailings and up to 440 kg of waste rock every year.⁷⁰

As of 2007, there were 216 million tonnes of uranium mill tailings in storage at 24 tailings sites across Canada⁷¹[Fig.19] -- enough material to fill the Toronto Rogers Centre approximately 100 times.

69 World Nuclear Association. Uranium in Canada. www.world-nuclear.org

70 Pembina Institute. Uranium Mining: Nuclear Power's Dirty Secret. www.pembina.org

71 Statistics Canada. Table 3.6 Radioactive waste in Canada. www.statcan.gc.ca

| Radioactive Waste in Canada | | | | |
|---|------------------------------------|---|------------------|---|
| | Accumulation rates in 2007 | Radioactive waste inventory 2007 | | Projected radioactive waste inventory 2050 |
| | cubic metres per year | cubic metres | | |
| Nuclear fuel waste | 311 | 8 130 | 21 300 | |
| Intermediate-level radioactive waste | 890 | 30 350 | 79 000 | |
| Low-level radioactive waste | 4 560 | 2 330 000 | 2 570 000 | |
| | millions of tonnes per year | millions of tonnes | | |
| Uranium mine tailings | 0.7 | 216 | ... | |
| Waste rock | ... | 175 | ... | |

Fig.19: Radioactive Waste in Canada. Data from Statistics Canada.

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In a 2014 report from the U.N. Intergovernmental Panel on Climate Change, research suggested that the process of uranium mining produces lower levels of GHGs in

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comparison to other industries. The research revealed that the mining and milling of uranium contributes about 12 grams of GHGs per kilowatt-hour of electricity produced from that uranium.⁷² By comparison, coal produces over 800 grams of GHGs per kilowatt hour and natural gas about 500 grams.⁷³

Although the releases are low for the actual mining process, the transport of uranium pellets to the transport of the radioactive waste material from nuclear power plants adds up to millions of kilometers in travelled distance.

In a 2016 performance report out of OPG, over 100,000 kilometers were traveled in their second quarter alone.⁷⁴

72 IPCC, 2014. Climate Change 2014: Mitigation of Climate Change.

73 Ibid.

74 Ontario Power Generation. Performance Report for Decommissioning & Nuclear Waste Management. Q2, 2016. www.opg.com

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This distance is solely from the radioactive waste from the Darlington and Pickering plants, which are transported to OPG's Western Waste Management Facility, located in Kincardine, Ontario, along the shores of Lake Huron. At the end of December, a total of 3.71 million kilometers had been traveled.⁷⁵

There is transport of nuclear substances continually, with millions of packages transported every year around the world. John Jackson with the Canadian Environmental Law Association(CELA), had this to say about the transportation of these packages:

75 Ontario Power Generation. Performance Report for Decommissioning & Nuclear Waste Management. Q3, 2016. www.opg.com

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"What's important to remember is that radioactive materials are constantly on the move around and across the Great Lakes. Whether it is fuel being shipped from a processing facility to power plants, waste being moved to storage sites, or tritium being shipped to a factory, these materials aren't just sitting in one place ... this opens up a real risk for accidental releases into the lakes themselves or into waterways that flow into the lakes."⁷⁶

- John Jackson,
Canadian Environmental Law Association

Due to the waste product created from the nuclear industry, transportation emissions are high, as well as the risks involved with each shipment. With other industries such as solar and wind, there is no constant waste product, and their materials can be recycled upon end-of-life. This process of operations is dangerous, and a key weak point for the nuclear industry.

76 CELA. 100+ groups call for designation of radionuclides as a Great Lakes "chemical of mutual concern". www.cela.ca

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'Low-Cost'

MacKinnon portrayed nuclear power as 'low-cost', a look at its' recent history of cost actually reveals a steady increase. There are two nuclear electricity generating companies in Ontario: Ontario Power Generation (OPG) and Bruce Power. In a February report by the OCAA, it was highlighted that since 2002, OPG's price of nuclear power increased by 60% from 4.3 to 6.9 cents per kWh; concurrently, Bruce Power's rates rose by 54% from 4.3 to 6.638 cents per kWh [Fig.20].⁷⁷ As a result of the increase and Ontario's current electricity surplus, prices have been driven up in the province. Current peak price of electricity in Ontario is set at 18 cents per kWh⁷⁸ [Fig.21], which is one of the highest rates in the country.

Adding further insult to injury, in September 2016, OPG

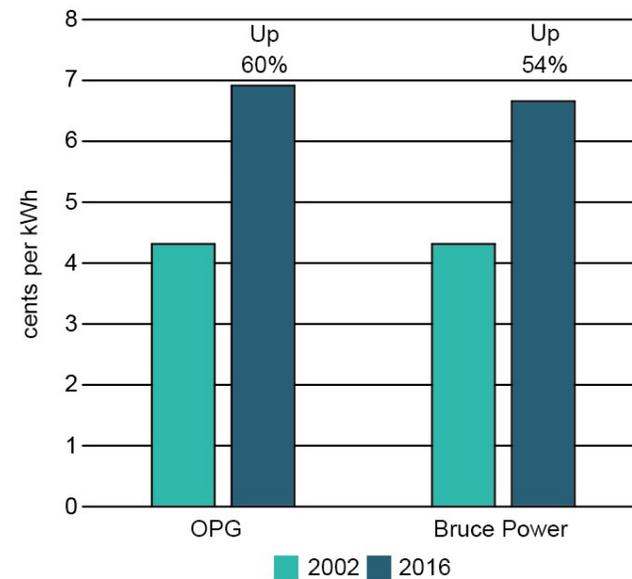


Fig.20: Nuclear Prices: 2002 vs. 2016. Data from OCAA.

77 Ontario Clean Air Alliance. Ontario's Rising Electricity Rates: The Role of Nuclear Power. www.cleanairalliance.org

78 Ontario Energy Board. Electricity Prices. www.ontarioenergyboard.ca

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announced that it would be seeking permission from the Ontario Energy Board to raise its price of nuclear power by an additional 180% to 16.8 cents per kWh by 2026 in order to finance the continued operation of the Pickering facility as well as the refurbishment of the Darlington plant.⁷⁹ This proposed price increase is based on the assumption that the \$12.8 billion refurbishment is completed on time, but as history has shown us, the possibility of the project going over budget is quite probable.

There are much better cost alternative methods of electricity production besides nuclear, with the current ideal situation of importing power from Quebec. In October 2016, Ontario signed an electricity contract with Hydro Quebec to provide it with 2 billion kWh of water power per year at a price of 5 cents



Fig.21: Ontario Electricity Rates(effective November 1, 2016). Data from Ontario Energy Board.

79 Ontario Clean Air Alliance. Ontario's Rising Electricity Rates: The Role of Nuclear Power. www.cleanairalliance.org

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per kWh for seven years.⁸⁰ With the existing transmission lines in place, power can be imported sufficiently from Quebec to displace all of Pickering's production. Furthermore, according to the Independent Electricity System Operator (IESO), it would cost Ontario approximately \$2 billion to upgrade its transmission system to enable us to import enough power to also avoid the need for the Darlington refurbishment.⁸¹

With other alternatives available, Ontario has chosen the route of nuclear energy, confirming their position as a main provider of Ontario's electricity supply for at least the next three decades. This continuous operation of nuclear facilities will continue to produce waste material which will ultimately need to be put in permanent protective storage; the appropriate response deemed by the OPG is in the construction of a Deep Geologic Repository(DGR).

80 Ontario Clean Air Alliance. Ontario's Rising Electricity Rates: The Role of Nuclear Power. www.cleanairalliance.org

81 Ontario Clean Air Alliance. Ontario's Rising Electricity Rates: The Role of Nuclear Power. www.cleanairalliance.org

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Deep Geologic Repository

OPG has safely transported, processed and stored low and intermediate-level nuclear waste for almost 50 years in above ground storage facilities. As an obligation to future generations however, OPG has proposed to dispose of this waste safely and responsibly where it cannot pose a threat to the public or the environment.⁸²

Their proposal is for the construction and operation of a Deep Geologic Repository[Fig.22] for the long-term management of low and intermediate-level nuclear waste. The proposed site sits adjacent to the current Western Waste Management Facility in Kincardine, Ontario, isolated from the surface at 680 metres underground in

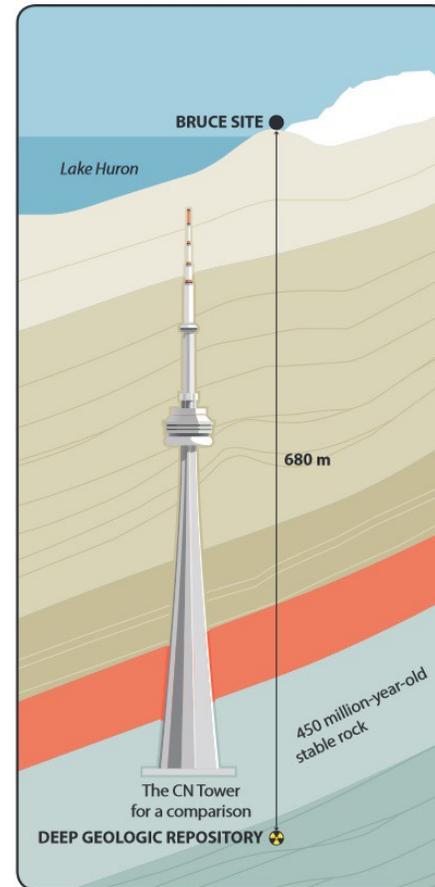


Fig.22: Deep Geologic Repository. Source: OPG.

82 Ontario Power Generation. Deep Geologic Repository. www.opg.com

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stable rock formations that are more than 450 million years old.⁸³

In February of 2016, The Minister of Environment and Climate Change, Catherine McKenna, requested additional information and further studies on the environmental assessment for the proposed DGR in Kincardine, as well as other possible locations for the repository.

The nuclear industry has been steadily building up an inventory of spent uranium bundles which require storage in the DGR. Heading the search for a secure place to store those bundles is the Nuclear Waste Management

83 Ontario Power Generation. Deep Geologic Repository. www.opg.com

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Organisation(NWMO), funded by Canada's four nuclear agencies, which describes the situation this way:

"If Canada's entire current inventory of just over two million used fuel bundles could be stacked end-to-end, like cordwood, it would fit into six NHL-sized hockey rinks from the ice surface to the top of the boards."⁸⁴

Completed in December 2016, the studies show that OPG could build the DGR elsewhere in Ontario, but with additional delays, risks and environmental effects adding up to \$3.5 billion in costs, largely due to transporting the existing waste to a new site.⁸⁵

Progress continues toward a decision expected mid-2017 by the Canadian Environmental Assessment Agency(CEAA), followed by the Minister's decision by the fall. If approved, OPG claims the DGR could be in service in 10 years, offering a definitive plan for the storage of its ever-growing collection of radioactive waste.

84 MacInnes-Rae, Rick. Canada narrows list of possible locations for nuclear waste facility. www.cbc.ca

85 Ontario Power Generation. Neighbours Newsletter: DGR for nuclear waste: A lasting solution, for peace of mind. Winter 2016.

DECOMMISSIONING

The redevelopment and reuse of nuclear facilities following decommissioning is an option that is currently not practiced to its full potential. With the upcoming fleet of retiring nuclear reactors there is increased interest in reuse of existing infrastructure and nuclear sites. These sites can provide increasingly valuable industrial or public land, which are usually situated adjacent to bodies of water and are important to preserve.

If the reuse potential of facilities or sites is identified at an early stage, decommissioning costs can be significantly lower due to the influence by the redevelopment and reuse options when engineering new facilities.⁸⁶ This approach of early redevelopment and reuse ensures that the best use is made of the infrastructure and land resources associated with the sites which can help to minimize decommissioning waste, both radioactive and non-radioactive.⁸⁷

Nuclear sites have the additional complication of potential radioactive contamination. Removal of these materials is necessary for the safe repurposing of the site and to ensure the protection of the surrounding community and

⁸⁶ IAEA. *Redevelopment and Reuse of Nuclear Facilities and Sites: Case Histories and Lessons Learned*. IAEA Nuclear Energy Series No. NW-T-2.2. Pg.1.

⁸⁷ Ibid.

decommissioning

environment. The presence of contamination is an additional barrier to the redevelopment of the site and construction of new facilities. According to the IAEA, early assessment of each site is critical to confirm existing conditions and minimize the impact of poor site planning.⁸⁸ This approach to reusing facilities/sites ultimately contributes to a more sustainable approach to the decommissioning of nuclear power plants.

Currently there are three main methods to decommissioning, each with their own advantages and disadvantages, but each useful in separate circumstances.

Radiation Associated With Decommissioning

The decommissioning of a nuclear facility can create large amounts of radioactive waste, the majority consisting of Low-Level Waste (LLW)⁸⁹; usually the steel and concrete building materials surrounding the reactor. High-Level Waste (HLW) from decommissioning consists mainly of reactor components, this waste contains isotopes that emit radiation as they decay.⁹⁰ The initial release of radiation decreases rapidly due to the relatively short half-life* of a number of isotopes [Fig.23]. After 50 years,

88 IAEA. Redevelopment and Reuse of Nuclear Facilities and Sites: Case Histories and Lessons Learned. IAEA Nuclear Energy Series No. NW-T-2.2. Pg.1.

89 United Nations Environment Programme. UNEP Year Book 2012: Emerging issues in our global environment. Pg.40.

90 Ibid.

Radiation Associated With Decommissioning

the radiation level in most decommissioning waste decays to a small percentage of the initial level.⁹¹

| Isotope | Half-life (years) |
|---------------------|-------------------|
| Uranium-238 | 4.5 billion |
| Uranium-235 | 700 million |
| Cesium-137 | 30 |
| Strontium-90 | 28.9 |
| Hydrogen-3(Tritium) | 12.3 |
| Iodine-131 | 8.04 days |

Fig.23: Some isotopes related to nuclear energy production, with their respective half lives. Data from Encyclopaedia Britannica.

At very high doses radiation can cause radiation sickness, cancers and even near-term or immediate death, as in the case of the two on-site workers at the time of the Chernobyl accident (See Chernobyl Chapter). At lower doses it can still induce cancers and genetic damage, as described by Dr. Ian Fairlie in the Chapter on tritium. At doses normally received during operations or decommissioning, however, risks to workers should be negligible.⁹²

The radiation encountered during decommissioning and the disposal of the waste generated is almost exclusively beta and gamma radiation⁹³[Fig.24]. Decommissioning risks are mostly associated with exposure to these types of radiation. Since the waste from decommissioning is most commonly in solid form, only unintended releases of radioactive dust generated during

⁹¹ United Nations Environment Programme. UNEP Year Book 2012: Emerging issues in our global environment. Pg.40.

⁹² Ibid.

⁹³ Ibid.

Radiation Associated With Decommissioning

demolition has the potential to result in exposure to the general public.⁹⁴

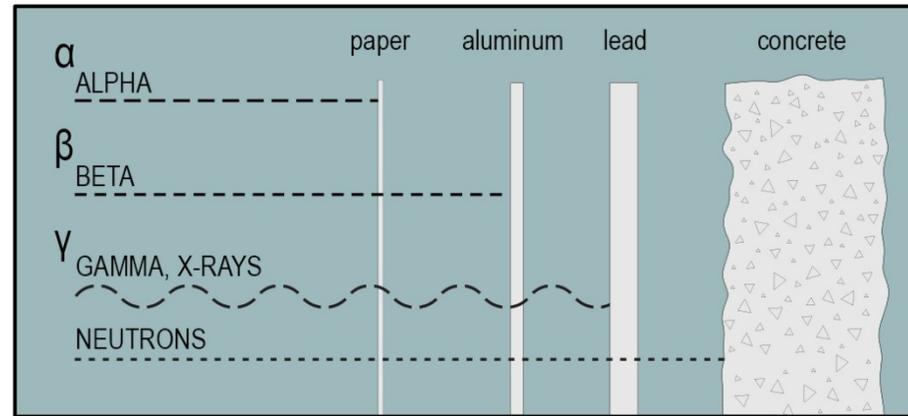


Fig.24: Alpha, beta, gamma and neutron radiation require different forms of protection. Alpha particles can be blocked by a sheet of paper, while beta particles cannot penetrate a thin piece of aluminium, gamma rays by heavy metals, such as lead or by concrete, and neutrons by concrete or water. Based from UNEP diagram.

decommissioning

Three Methods of Decommissioning

The primordial concept of decommissioning management for nuclear facilities was that of a closed life cycle, which involved the final disposal of waste and the restoration of the site to its original state.⁹⁵ This concept is no longer the only option. The International Atomic Energy Agency (IAEA) has defined three options for decommissioning which have been internationally adopted:

Definitions Source: UNEP Year Book 2012. Pg.37-39.

Immediate Dismantling⁹⁶

All equipment, structures and other parts of a facility that contain radioactive contaminants are removed (or fully decontaminated) so that the site can be treated as uncontaminated for either unrestricted or more restricted use (sometimes referred to as a 'greenfield' site). This internationally agreed approach has the advantage

95 IAEA. Redevelopment and Reuse of Nuclear Facilities and Sites: Case Histories and Lessons Learned. IAEA Nuclear Energy Series No. NW-T-2.2. Pg.1.

96 United Nations Environment Programme. UNEP Year Book 2012: Emerging issues in our global environment. Pg.37-38.

decommissioning

that experience operational staff from the facility are still available who know the history of the site, including any incidents in the past that could complicate the decommissioning process. Immediate dismantling also avoids the unpredictable effects of corrosion or other degradation of the reactor parts over an extended period, eliminates the risk of future exposure to radiation, and removes a potential blight on the landscape. A disadvantage of this approach is that levels of radioactivity in the reactor parts are higher than in the case of deferred dismantling, and that larger volume of decommissioning waste will be classified as radioactive.

Deferred Dismantling⁹⁷

After all the spent fuel is removed, the plumbing is drained, and the facility is made safe while

decommissioning

dismantling is left for later. This approach is often called 'safe enclosure'. The deferral periods considered have ranged from 10 to 80 years (Deloitte 2006). For instance, the Dodgewaard reactor in the Netherlands was shut down in 1997 but will not be decommissioned until at least 2047 (IAEA 2004). Deferred decommissioning has the advantage of allowing radioactive materials to decay to lower levels of radioactivity than in the case of immediate dismantling. This reduces both disposal problems and risks of harm to workers. In the meantime, robotic and other types of techniques that make dismantling safer and cheaper may undergo further development. A disadvantage is that some materials, including concrete and steel, may deteriorate, making the eventual decommissioning more difficult. Moreover, personal knowledge of a site's history will be lost as time passes.

decommissioning

Entombment⁹⁸

Once the spent fuel has been removed, reactors can be entombed. This involves encasing the structure in highly durable material such as concrete while its radioactivity decays. Entombment is a relatively new approach that is mainly considered in special cases (examples are small research reactors or reactors in remote locations). It can reduce worker exposure to radioactivity since there is less handling of contaminated materials. However, long-term maintenance and monitoring are required. Five reactors have been entombed in the United States, with the entombment of two reactors at the Savannah River site completed in 2011.

98 United Nations Environment Programme. UNEP Year Book 2012: Emerging issues in our global environment. Pg.38-39.

decommissioning

There are several decommissioning strategies possible beyond these main three, with many of these strategies having been used worldwide. Each facility and site should be treated on a case by case basis, with each requiring their own appropriate response to achieve the most optimal decommissioning strategy. The international nuclear community has deemed immediate dismantling as the best practice. One of the most recent facilities to have practiced this strategy is the Maine Yankee Nuclear Power Plant.

decommissioning

Maine Yankee Nuclear Power Plant

The Maine Yankee Facility[Fig.25] operated a 900 megawatt three-loop pressurized water reactor on a 180 acre site adjacent to the Back River, in Wiscasset, Maine. The facility, which operated from 1972 - 1996, produced approximately 119 billion kilowatt-hours of electricity during that time.⁹⁹

In the mid 1990's, the plant encountered various operational and regulatory complications. In 1995 it was shut down for almost the entire year to repair steam generator tubes.¹⁰⁰ In the following year, Maine Yankee would encounter further problems, including improper



Fig.25: Maine Yankee Nuclear Power Plant.
Source: www.bangornewsdaily.com

99 Maine Atomic Power Company. Maine Yankee: An Interim Storage Facility for Spent Nuclear Fuel. www.maineyankee.com
100 Electric Power Research Institute. Maine Yankee Decommissioning. Pg.25.

decommissioning

cable separation, replacement of a number of leaking fuel rods and the need to inspect the plant's steam generators, which led the plant to shut down for the final time on December 6, 1996.¹⁰¹

On August 6, 1997, the Maine Yankee Atomic Power Company Board of Directors voted to permanently cease power operations and immediately initiate the decommissioning process. The decommissioning approach selected (immediate dismantling) followed the economic analysis of the Board of Directors which noted that that "the prompt approach was the most economically advantageous to the ratepayers."¹⁰²

101 Electric Power Research Institute. Maine Yankee Decommissioning. Pg.25.

102 Ibid. Pg.27.

decommissioning

The plant was successfully decommissioned between 1997-2005. Structures were removed and the site was restored to stringent federal and state remediation standards confirmed in October 2005, by the U.S. Nuclear Regulatory Commission (NRC).¹⁰³

The decision was made to store the remaining radioactive material on site, in what is now the Independent Spent Fuel Storage Installation (ISFSI)[Fig.26], which consists of 60 dry storage casks containing 1434 spent nuclear fuel (SNF) assemblies used during the operating life of the plant and 4 casks containing sections of the reactor vessel internals.¹⁰⁴ The ISFSI is located on approximately 11



Fig.26: Independent Spent Fuel Storage Installation(ISFSI) on the decommissioned Maine Yankee Site. Source: www.3yankees.com.

¹⁰³ Maine Atomic Power Company. Maine Yankee: An Interim Storage Facility for Spent Nuclear Fuel. www.maineyankee.com
¹⁰⁴ Ibid.

decommissioning

acres of the 180 acre Maine Yankee site, acting as an interim storage facility until a permanent location has been selected.

RESEARCH SUMMARY

From what history has shown, nuclear energy is a powerful force; a force which to humanity is still uncontrollable. With that in mind, nuclear facilities will continue to be constructed throughout the world, and as such, with fingers crossed, will reach their end lives, only to be dismantled; requiring further protective containment. Today, there are already several facilities around the world that are running past their design lives. These facilities will need to be decommissioned in the near future, offering multiple new business opportunities for the nuclear sector.

With the Pickering Nuclear Generating Station set to close, there is an opportunity here in Canada to explore new possibilities in decommissioning, including site and facility repurposing. As experts agree, the immediate dismantling of Pickering would be the best practice following its shutdown, but with waste storage still a problem that has yet to be resolved, a more responsible approach to decommissioning must be derived.

The following chapters will explore a potential decommissioning strategy; utilizing infrastructure reuse, site revitalization, as well as examining projections for local and world issues to develop a new program for the Pickering Nuclear site.

DESIGN

PROGRAM DEVELOPMENT

In a 2015 report from OPG, a study was undertaken exploring possible future uses of the Pickering site. The reason for the study was "to ensure that the site will continue to be put to productive uses that benefit Ontarians during and after the decommissioning of the Pickering station."¹⁰⁵

Through public input and stakeholder engagement activities, a list of more than 600 options was generated for repurposing Pickering. After further assessment, these options were divided into four categories deemed suitable for implementation: power, industrial, institutional and recreational. This categorization was directly related to the input given by the public [Fig.27].¹⁰⁶

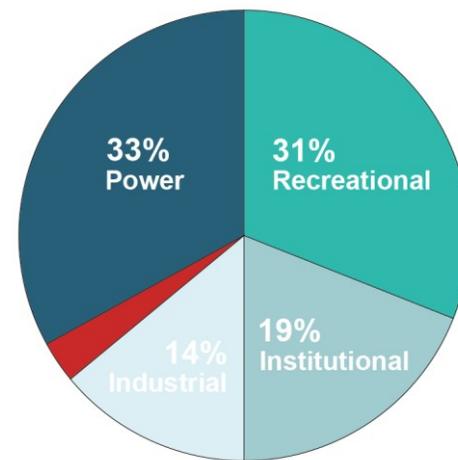


Fig. 27: Public input options.
Data from www.opg.com

¹⁰⁵ Ontario Power Generation. "Repurposing Pickering". December 11, 2015. www.opg.com. Pg.3.

¹⁰⁶ Ibid.

program development

These divisions, alongside current conditions on-site and in its surroundings will serve as important guides for the appropriate development of future uses for Pickering. Some important conditions to consider are:

- The proximity to important bodies of water and wildlife habitat
- The surrounding infrastructure, as well as a large workforce on site
- The potential for transporting large shipments by rail or ship
- The connectivity to the existing hydro corridor
- The projected population growth for the City of Pickering (to double by 2031)¹⁰⁷

107 City of Pickering. "Demographics & Statistics". www.pickering.ca

program development

Pickering Nuclear Site

The Pickering station is located on the shores of Lake Ontario, south of Montgomery Park Rd and within the Brock Industrial Area. In total, OPG owns about 500 acres of land and 250 acres of water lots at or adjacent to the Pickering station [Fig.28].¹⁰⁸

The site's main access road is Brock Road, which connects to the major highways in the area. Although not currently in use, the site is also accessible from the lake via a dock (which was built during construction of the station to facilitate unloading of major reactor components).¹⁰⁹ With regards to rail transport, the site is situated within 3.5 km of the nearest



Fig. 28: OPG Property.

108 Ontario Power Generation. "Repurposing Pickering". December 11, 2015. www.opg.com. Pg.11.
109 Ibid. Pg.12.

program development

Canadian National Railway line.

Apart from the nuclear facilities, OPG operates several other structures on the site, including a 1.8MW wind turbine, office buildings, a training centre, a public information centre, and buildings for maintenance and storage. The site also contains two landfills that were created during construction of the station -- both containing conventional construction wastes and are now heavily vegetated.

The north-western portions of the site are licensed to the City of Pickering and used for public recreational uses, including: a beach, parkland (Alex Robertson Park) and sports fields for baseball, cricket, soccer and tennis (Bay Ridges Kinsmen Park).

program development

On the shoreline, to the south of the reactors, is the site's very own water treatment facility, responsible for all water that is used at the station. The site is also equipped with its own intake and outfall system for cooling the reactor units.¹¹⁰

The site's total frontage along the shoreline of Lake Ontario is approximately 2,260 meters.¹¹¹ No natural shoreline exists on site, as it was modified extensively during the construction of the nuclear facilities [Fig.29].



Fig.29. Pickering Nuclear Generating Station. Source: www.opg.com

110 Ontario Power Generation. "Repurposing Pickering". December 11, 2015. www.opg.com. Pg.12.

111 Ibid. Pg.56.

program development

Site Surroundings

The Pickering Nuclear site is surrounded by residential and recreational areas to the north-west, the hydro corridor the north, industrial areas to the north-east and east, and Lake Ontario to the south [Fig.30]. Directly adjacent to the site on its east side is the Duffin Creek Water Pollution Control Plant [Fig.31], which treats wastewater from both Durham and York Regions. This facility has operated alongside the Pickering station, utilizing outdated processes for wastewater treatment; providing opportunities for replacement with new innovative technologies.

Due to its sensitive content, the Pickering site exists as a highly privatized zone along the lakeshore. The entire site



Growth or Decay

Fig.30: Site Surroundings.

program development

remains fenced off to the public, which disrupts the Waterfront Trail running through Pickering [Fig.32]. This trail is made up of an interconnected series of trails that begins in Niagara-on-the-Lake, Ontario, and extends to Brockville, Ontario. Incorporating a new route through the site upon redevelopment would help to re-engage the public with this newly available property along the lakeshore.

Besides Lake Ontario, the Pickering site is located close to several other important bodies of water, including Hydro Marsh, Duffin Creek and Frenchman's Bay. These water bodies provide important habitat for local ecosystems, as well as opportunities for environmentalists and recreationalists.



Fig.31: Duffin Creek Water Pollution Control Plant.
Source: www.stockaerialphotos.com

THE WESTERN GATEWAY

Pickering's section of the Waterfront Trail begins in the West with a raised pedestrian crossing of the Rouge River.

PETTICOAT CREEK CONSERVATION AREA

Petticoat Creek Conservation Area offers a continuous section of the Waterfront Trail and a 1.5 acre supervised wading pool.

PETTICOAT CREEK BRIDGE

170 metres of elevated boardwalk over the Petticoat Creek.

ROTARY FRENCHMAN'S BAY WEST PARK

A special place of outstanding natural features in an urban setting; protected, managed and fostered by the local community and service groups.

BRUCE HANDSCOMBE PARK

A popular location for children's play, fishing, and strolling, connecting pedestrians to other key waterfront points of interest.

PROGRESS FRENCHMAN'S BAY EAST PARK

Included at this location is a decorative gazebo, a creative play unit, seating, lighting, a parking area, lake access for canoes and windsurfers, and fishing docks.

MILLENNIUM SQUARE

A large public square located at the southern end of Liverpool Road, perched on the shore of Lake Ontario, where regularly scheduled events and festivals bring the area to life.

BEACHFRONT PARK

Beachfront Park is accessed from the southern end of Liverpool Road. With Lake Ontario lying south of the park and the Hydro Marsh located to the north, the park provides ample opportunities for recreation and nature appreciation. Facilities include: children's splash pad play area, seasonal washrooms, 2 beach volleyball courts and a creative play unit.

HOMEPLACE

Explore the imagination of Pickering artist Dorsey James by visiting this fabulous sculptural installation. Subtitled by it's creator as "Enchantment in the Making"

DUFFINS CREEK CROSSING

A crossing of the Duffins Creek leads to the Town of Ajax.



Fig.32: The Waterfront Trail. Source: www.discoveringdurham.ca

program development

Frenchman's Bay

Frenchman's Bay [Fig.33] has been designated as an Environmentally Sensitive Area by the Toronto Region Conservation Authority due to its diversity of vegetation and significant natural features. The bay is defined by a strip of sandy land that separates Lake Ontario from the bay itself. This "barrier beach" is a dynamic beach and sand dune system that is a critically important and rare coastal ecological community that can be found in only a few locations within the Greater Toronto Area.¹¹²

Some of the region's best surfing and kite boarding can be done here. The parks location and



Fig.33: Frenchman's Bay. Source: www.utsc.utoronto.ca

112 City of Pickering. "Rotary Frenchman's Bay West Park". <https://www.pickering.ca>

program development

configuration provide for perfect winds and waves along the kilometer long sandy beach. However, recreational activities on the bay are not restricted to the summer months. During the winter season, the bay provides ample space for ice skating, fishing, as well as the odd iceboat; activities which have thrived here for decades [Fig.34&35].



Fig.34&35: Ice Boating & Ice Fishing, 1969. Source: Pickering-Ajax Digital Archive.

program development

City of Pickering

As the gateway to the east GTA (Greater Toronto Area), the city of Pickering (population 94,000) is strategically located where Toronto, York and Durham Regions meet. An award-winning municipality, Pickering is slated for significant economic and residential growth. Its dynamic City Centre has been designated by the Province of Ontario as both an Urban Growth Centre and Mobility Hub,¹¹³ and continues to evolve as a preferred destination for creative learning, memorable events, and unique experiences at the



Fig.36: The City of Pickering. Source: www.pickeringlimoairport.ca

G r o w t h

113 City of Pickering. "Destination Pickering". May 18, 2017. www.pickering.ca

heart of a vibrant, connected, and engaged community.

For several decades, Ontario Power Generation (OPG) has been the largest employer in Pickering. Today it employs 4,500 employees¹¹⁴ made up of a wide range of people from nearly every trade, profession and skill set.

With the closure of the Pickering plant, these employees could prove to be invaluable. A strategy which incorporates a large workforce, specifically in relation to the workforce at OPG, would ensure the continued success of the site, as well as for the City of Pickering.

114 City of Pickering. "Major Employers". www.pickering.ca

PROPOSED PROGRAM

The Pickering site offers ample opportunity for a multitude of program to operate. A best-case scenario would be to incorporate several different programs into a uniform design which would be publicly accessible; opening up 2 kilometers of shoreline to the city's locals and tourists.

The difficulty in proposing a program for the site is in the fact that it cannot be something that is designed for today. Following the shutdown of the nuclear plant -- which could be from 1 to 10 years from now (depending on government approval) -- it would take at least another couple decades to store the accumulated nuclear waste, as well as decommission most of the infrastructure; even longer if the decommissioning process follows the proposed timeline set by OPG (+40 years).¹¹⁵ This results in a program selection which must directly reflect the needs of the future populace.

115 Ontario Power Generation. "Repurposing Pickering". December 11, 2015. www.opg.com. Pg.16.

proposed program

One of the most crucial issues moving forward is the maintenance of Lake Ontario water quality. Lake Ontario provides drinking water for several million people in both Canada and the United States, as well as offers a refreshing retreat for beach-goers in the summer. However, each summer offers instances where the lake water quality is unsafe for swimmers. This is largely due to elevated E. coli levels in the lake water, which are most commonly caused by excess rainfall being released into the lake from over-capacitated storm drains.

It is even more concerning that this year the newly elected President Trump plans to cut the Environmental Protection Agency's (EPA) budget by \$2.6 billion from its

proposed program

budget of \$8.1 billion in 2016;¹¹⁶ that is a 31 percent budget reduction for the EPA. Of that \$8.1 billion, \$300 million was directed towards the Great Lakes Restoration Initiative, but due to the new budget cuts by The Trump administration, this program would have its budget slashed down to a mere \$10 million,¹¹⁷ eliminating several restoration projects or forcing them to scramble to find funding to support their initiatives.

Another important aspect to consider is the continued production of electricity on-site or in its proximity. For nearly five decades Pickering has been a leader in energy production. Moving forward it is critical that municipalities contribute to their own modes of energy

116 Holden, Emily, Evan Lehman & E&E News. "Trump Budget Cuts Funds for EPA by 31 Percent". Scientific American. March 16, 2017. www.scientificamerican.com
117 CBC News. "Leaked U.S. funding slash for Great Lakes cleanup reverberating in Hamilton". March 7, 2017. www.cbc.ca

proposed program

production; more specifically renewable energy production. Electricity has become a necessity for modern day life; it drives us, connects us, and facilitates daily operations. The continued production of electricity at the Pickering site ensures increased electrical reliability for the City, as well as provides multiple job opportunities for current OPG employees who will need to adapt to future change in their job sectors.

The final program choice is that of Agriculture. The concept of growing food in cities has grown enormously in the past decade. Humanity's hunger for excess and variety in their food choices has proven to be unsustainable. The current system of food production, from pesticide use, to cultivation, to transportation, and

proposed program

then inevitably to the garbage as waste is a system loaded with flaws. We are currently seeing great rises in food prices, this is largely due to production in countries closer to the equator who are experiencing record lengths of drought from climate change. Integrating agriculture within urban settlements will help to eliminate many problems of the current system, and can help to create closed-loop systems to create more sustainable cities. Appropriate municipal support is crucial to the wider adoption and success of urban agriculture.

These three domains will make up the main program for the redesign of the Pickering site; accompanied by several other smaller program to help form a sustainable environment for the City of Pickering.

proposed program

Energy

In a 2013 report out of Europe, 58 countries were evaluated based on their commitment to climate change policy; Canada placed 55th of the 58 countries in terms of tackling greenhouse gas emissions, ahead of only Iran, Kazakhstan and Saudi Arabia.¹¹⁸ Furthermore, in the same year, a Washington-based group, the Center for Global Development, issued a separate report that ranked Canada 27th on the environment out of the world's wealthiest 27 countries.¹¹⁹

Since then, there has not been much improvement in terms

118 The Canadian Press. "Canada ranks worst on climate policy among industrialized countries: report". Maclean's. November 18, 2013. www.macleans.ca
119 Ibid.

proposed program

of climate policy. The most noteworthy development would be in terms of a carbon tax policy implemented by the Province of Alberta, as well as a cap-and-trade system implemented by the Province of Ontario. Both policies are only in their first year of operation, with Ontario's plan estimated to bring in \$1.9 billion a year, or \$8 billion by the end of 2020, to be invested in programs that reduce emissions.¹²⁰

It is clear that Canada needs to improve on its climate policy, and the hope is that with these new taxes new projects will unfold including more investments into renewable energy production.

¹²⁰ Jones, Allison, The Canadian Press. "Provinces considering carbon pricing are watching Ontario's first cap-and-trade auction". Financial Post. March 21, 2017. www.financialpost.com

proposed program

As a possible site for a renewable energy project, the Pickering site could incorporate several varieties of renewable energy. It is difficult to select the most appropriate type of renewable energy production, as the price for renewables -- specifically wind and solar -- continues to drop. It is an exciting time as businesses are in a race to develop more and more efficient technologies in the fight against climate change.

In the near future, when the Pickering Nuclear facilities have been decommissioned, several decades will have passed. This time frame will allow for the refinement of renewable energy sources to allow for increased efficiency. Here we will discuss a few different sources

proposed program

that show great potential for the future of energy production.

Wind

As of May 1st, 2016, the average electricity generation supply cost in Ontario is 11.14 cents per kilowatt hour, according to the Ontario Energy Board.¹²¹ New wind energy compares very favourably. In a September 2016 study out of the province's Independent Electricity System Operator, the IESO found that the levelized unit energy cost of wind is \$65-210 per megawatt hour,¹²² the lowest of any electricity generation option available to Ontario. By comparison, nuclear is \$120-290 per megawatt hour, hydro-electric power is \$120-240 per

121 Ontario Energy Board. *Regulated Price Plan: Price Report*. April 14, 2016. www.oeb.ca. Pg. 3.

122 IESO. "Planning and Forecasting: Ontario Planning Outlook". September 1, 2016. www.ieso.ca. Pg. 12.

proposed program

megawatt hour, natural gas is \$80-310 per megawatt hour, and solar photo-voltaic is \$140-290 per megawatt hour.¹²³

Unlike major generation technologies such as nuclear and hydro, wind energy's costs have declined dramatically and are forecast to continue declining. "The cost of onshore wind is expected to drop 41 per cent by 2040, driven primarily by improving capacity factors," according to Bloomberg's New Energy Outlook 2016.¹²⁴

Wind energy has been the largest source of new electricity generation capacity in Canada over the last decade.¹²⁵ It has become the electricity supply option of choice because many jurisdictions, such as Ontario, have provided stable policy that

123 IESO. "Planning and Forecasting: Ontario Planning Outlook". September 1, 2016. www.ieso.ca. Pg. 12.

124 Collins, Bryony. "Full steam ahead for low carbon energy by 2040". Bloomberg. June 20, 2016. www.bloomberg.com

125 CANWEA. "What is the most economic source of new electricity generation for Ontario?". October 21, 2016. www.canwea.ca

proposed program

has allowed industry to continually improve the technology. In addition, the wind industry has not produced a track record of significant cost overruns such as the case with the nuclear and hydro-electric industries -- plus there is no carbon price risk, as the fuel (wind) is free --.

The evidence is clear that wind energy has become the low-cost, emissions-free electricity source of choice around the globe, and an increased reliance on it here in Ontario makes great sense. A drawback of the technology for the Pickering site would be the land area needed to establish the many turbines needed to help procure enough energy for on-site activities as well as the surrounding community. In response to this drawback, many countries have chosen to implement offshore wind farms [Fig.37],



Fig.37: Offshore wind farm in Denmark. Source: www.thestar.com

proposed program

including the United Kingdom, Germany, Denmark, Netherlands, as well as the United States who just completed their first offshore wind project located off the shores of Rhode Island in the Atlantic Ocean [Fig.38].

The idea of an offshore wind farm is nothing new in Ontario. In fact, six years ago Ontario had plans with both Windstream Energy and Trillium Power Wind for offshore wind projects in Lake Ontario. However Ontario abruptly imposed a moratorium on the projects, citing the need for more research before a first-of-its-kind project to be implemented in the Great Lakes. Now, six years later, the moratorium is still to be lifted, with the government signaling it will likely continue for several more years, even with all of its studies completed to date. In a



Fig.38: Block Island wind farm, Rhode Island, New York.
Source: www.businessinsider.com

proposed program

statement out of the Ministry of the Environment captured by the Toronto Star, the next step for Ontario is to "continue to follow the impact of North America's first offshore wind pilot project in Lake Erie -- a project authorized by the State of Ohio... Doing so will allow us to have a better grasp of any potential environmental and health challenges posed by freshwater offshore wind development. The moratorium will not be lifted until research findings are understood and concerns surrounding offshore wind projects are addressed."¹²⁶

As the Lake Erie project is slated to begin construction in the spring of 2018, progress is still far off. But with the closing of the Pickering Plant, there is plenty of time for

126 Jones, Allison, The Canadian Press. "Ontario signals offshore wind moratorium will continue for several more years". The Toronto Star. February 13, 2017. www.thestar.com

proposed program

research and development to occur. Maybe one day there will be a wind farm off the shores of Pickering.

Solar

Solar energy is another industry which is gaining momentum around the world. In a report out of the trade group SolarPower Europe, solar energy capacity worldwide increased by 50 percent in 2016, and will continue to grow in the foreseeable future.¹²⁷ This is good news for many countries, as the rapidly falling price of solar photovoltaic panels now means that the solar industry can produce electricity at cheaper cost than coal, natural gas, and nuclear power.

127 SolarPower Europe. "Global Market Outlook 2017-2021: Solar Boom Continues". www.solarpowereurope.org

proposed program

The rapid growth in solar energy is being led by China, which last year installed nearly half of all new solar energy capacity. In the first quarter of this year alone, China's electricity output from photovoltaic plants rose 80 percent, boosting its total installed capacity to almost 85 gigawatts.¹²⁸

China is not alone in its solar energy production, as most recently new records have been broken in the UK for solar power as it provided nearly a quarter of the country's electricity needs. According to the National Grid, thousands of photovoltaic panels generated 8.7 gigawatts, or 24,3% of demand, smashing the previous record of 8.48

128 Bloomberg. "China's Solar Output Increased 80% in First Quarter". Bloomberg News. May 4, 2017. www.bloomberg.com

proposed program

gigawatts.¹²⁹

Today, two active solar technologies exist: Solar collectors or panels which are used to heat water or ventilation air for use in buildings and homes, and solar photovoltaic technology using solar cells to convert sunlight directly into electricity. The industry continues to develop, with several applications unfolding from voltaics being applied over building glazing, to replacing the entire roof of residential homes like that of Tesla's solar roof [Fig.39].

Canada's use of solar energy has increased in recent years, although it remains relatively small in comparison to other



Fig.39: Tesla Solar Roof, smooth option. Source: www.tesla.com

129 Vaughan, Adam. "Solar power breaks UK records thanks to sunny weather". The Guardian. May 26, 2017. www.theguardian.com

proposed program

countries. Installed capacity for solar thermal power has seen annual compound growth rate of 13.8 percent since 2004.¹³⁰ The 2008-2014 period was marked by the significant growth of installed capacity for solar power, which in 2014, reached 1,843 megawatts of installed capacity.¹³¹

With solar power however, comes the flaw that it is a technology that only produces electricity during times when the sun is shining. In response to this, the industry is combating this flaw through the addition of energy storage technology.

There are several types of energy storage which have

130 Natural Resources Canada. "About Renewable Energy: Solar Energy". www.nrcan.gc.ca
131 Ibid.

proposed program

progressed over the recent years, from large scale lithium batteries to Advanced Compressed Air Energy Storage (A-CAES). Hydrostor, a Canadian underwater energy storage company is leading the way with their A-CAES technology. Their storage process involves 4 steps:¹³²

1) Convert Electricity to Compressed Air

Electricity runs an air compressor which converts the electrical energy into compressed air. The compressed air stream is pressurized to the same pressure found at depth where the accumulators are located and the air is stored.

¹³² Hydrostor. *Advanced Compressed Air Energy Storage*. www.hydrostor.ca

proposed program

2) Capture Heat in Thermal Store

Heat from compression is captured from the airstream and stored to be used during generation, known as Adiabatic CAES. Adiabatic operation increases system efficiency while eliminating the need for additional heat from fossil fuel such as natural gas, avoiding fuel costs and emissions.

3) Store Compressed Air in Accumulator

Compressed air is stored within one of three types of Hydrostor Accumulators. In Hydrostor's Terra™ and Marine applications, compressed air displaces water in the accumulators at the

proposed program

hydrostatic pressure related to depth. In Cavern applications, an underground geological formation is utilized to store large volumes of air at variable pressure.

4) Convert Compressed Air to Electricity On Demand

To generate electricity on demand, the system reverses the air flow allowing pressure to force the air back to the surface. The stored heat is added back into the air stream. The now heated air travels through a turbo expander which drives a generator, efficiently converting the energy in the air back into electricity for the consumer.

With its immediate adjacency to the Lake, the Hydrostor

proposed program

Marine system [Fig.40] would make the most logical sense for the Pickering site. The marine system utilizes HydroPod, a rigid-walled accumulator structure designed for quick and simple underwater installation at depths of 150+ meters. The system is connected via drilled air communication pipe from shore, and utilizes hydrostatic pressure found at depth to maintain an isobaric (constant pressure) system during charge and discharge. Compressed air is pumped into the HydroPods displacing water in the accumulators during charge, with water displacing the air during discharge.¹³³

An energy storage system would complement renewable energy production on-site, yet even if energy production is

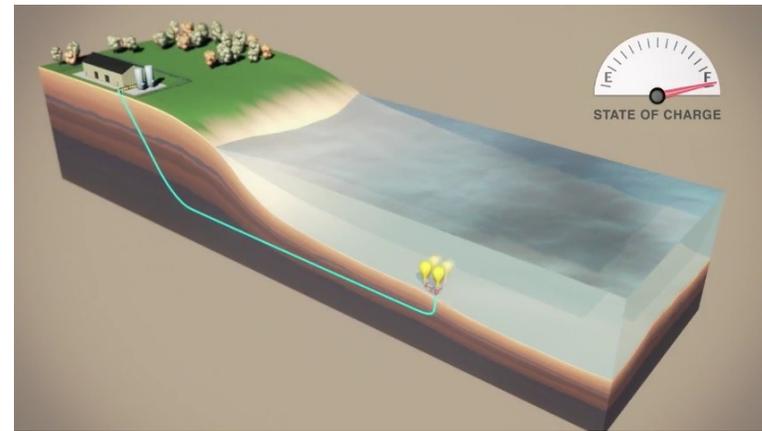


Fig.40: Hydrostor Marine System. Source: www.hydrostor.com

¹³³ Hydrostor. *Advanced Compressed Air Energy Storage*. www.hydrostor.ca

proposed program

not chosen to occur at the Pickering site, energy storage could still take place, drawing power from other energy projects through the existing hydro infrastructure.

Geothermal

Geothermal energy is nothing new, in fact it is one of the oldest modes of energy used by humanity. It also has the greatest potential for future energy production.

Geothermal energy is the heat from the Earth. It's clean and sustainable with resources of geothermal energy ranging from the shallow ground to hot water and hot rock found a few miles beneath the Earth's surface, or down even deeper to the extremely high temperatures of molten rock.

proposed program

Despite the many benefits of geothermal, Canada is the only "Pacific Ring of Fire" country that doesn't use it for commercial-scale energy. Countries like New Zealand, Indonesia, the Philippines, the United States and Mexico all have commercial geothermal plants, but not Canada. A groundbreaking study published in the Journal of Geophysics and Geoengineering found that there is great potential for geothermal energy production in Canada. The most promising Canadian sites are located in parts of British Columbia, Alberta and Saskatchewan at depths ranging from 3.5 to 6.5 kilometers.¹³⁴ However, if you drill deeper, the potential extends across the country -- including parts of Ontario [Fig.41].

134 Hamilton, Tyler. "Hamilton: Geothermal could meet Canada's power needs". The Toronto Star. May 17, 2010. www.thestar.com

proposed program

Geothermal power plants have much in common with traditional power-generating stations, including nuclear stations. They use many of the same components, including turbines, generators, transformers, and other standard power generating equipment. The benefit of course compared to nuclear, is that there is no bi-product created from its energy production, and it still produces constant electricity production like that of nuclear.

New methods of collecting energy from the ground could also give geothermal a boost. Entrepreneur and founder of the 5-hour Energy Drink Manoj Bhargava, is working with researchers at his Stage 2 Innovations company to bring heat to the surface using graphene cords rather than

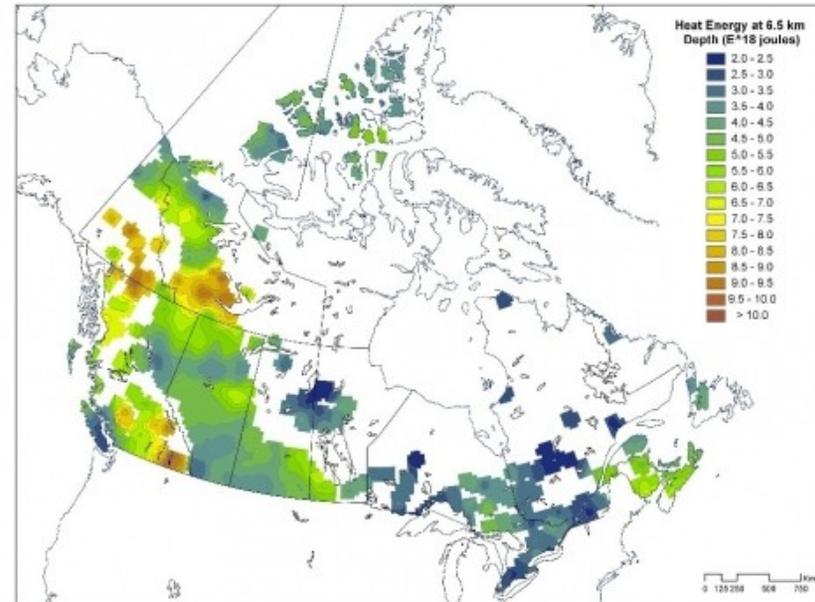


Fig.41: Geothermal heat potential in Canada. Source: www.pembina.org

proposed program

steam or hot water. Graphene, a recently discovered allotrope* of carbon, is stronger than steel and is a better conductor than copper.

In a video posted online, Bhargava details the characteristics of the material,

"It transfers heat really efficiently. If you put 100 degrees here, you get 100 on the other side instantly, in the middle it's completely cool. So the heat that you put in gets all the way there, whether you'd go 10 feet or you go miles, you could bring up unlimited energy from deep underground to the surface, pollution free."

Bhargava praises the technology as the possible biggest

proposed program

invention ever created, and for good reason. The prospect of a technology that could produce limitless energy, while doing so with zero GHG emissions could prove to be absolutely game-changing.

The fact remains that this technology -- though proven to work in its initial testing -- is still some time off before commercial production. But with the amount of time before the Pickering site can be reused, there will be plenty of time to refine such technology, as well as any other source of renewable energy deemed appropriate for application at the site.

proposed program

Water Infrastructure

One of the largest issues humanity faces around the world today is access to fresh water. Due to climate change we are seeing more and more cases of intense drought in countries across the equator. Even in states in the U.S., including California, drought has been a huge issue. This year has brought some relief however, as above average precipitation has helped to end California's drought state of emergency after five parched years.¹³⁵ These high precipitation levels, though a blessing for many areas with drought, can also be quite destructive, as is the case currently surrounding Lake Ontario.

135 United States Geological Survey. "Is the drought over?". USGS. May 31, 2017. www.ca.water.usgs.gov

proposed program

This year (2017), Lake Ontario water levels have been recorded at their highest ever --breaking a record that has stood since 1952 -- according to data from the U.S. Army Corps of Engineers.¹³⁶ An examination of Pickering's historical weather data revealed that in the month of May alone, precipitation levels have exceeded those of 2016 by almost four times -- from 42.1mm to 161.6mm.¹³⁷ In addition to the local precipitation around Lake Ontario, the Lake is also receiving a lot of water from the Upper Great Lakes, which flows through Lake Ontario before releasing into the St. Lawrence River.

The record breaking water levels are threatening many

136 Goffin, Peter. "Toronto braces for more rain with Lake Ontario at record-breaking levels". The Toronto Star. May 26, 2017. www.thestar.com

137 The Weather Network. *Pickering, ON*. www.theweathernetwork.com

proposed program

areas around the lake, including Toronto's Centre Island, which has been hit with high flood waters [Fig.42]. For the first time in 50 years, Centreville missed its scheduled May 6th opening for summer operations due to the water levels.

Other areas around the city have also been affected by the elevated water levels. Many cities are experiencing mass soil erosion along their lakefront. The town of Ajax, adjacent to the City of Pickering, incurred heavy damage to its lakefront [Fig.43], shutting down parts of the waterfront trail which runs along the lake.

It is with these large rainfalls that Lake Ontario becomes unsuitable for swimming. Following a storm, large



Fig.42: Flooding on the Toronto Island. Source: www.thestar.com



Fig.43: Ajax waterfront trail. Source: www.cbc.ca

proposed program

amounts of water flows into the lake, carrying with it animal waste, pollutants and toxic chemicals from parks, woodlands, lawns and fields. This leads to elevated risks of contracting E.coli or other harmful illnesses. The Lake Ontario Waterkeeper, a Canadian water charity, has been collecting data on Lake Ontario's water quality since 2009. They relay such information to the public through the Swim Guide, a website and smartphone app that helps to inform beach-goers of the water quality at their local beaches.

The closest beaches surrounding the Pickering site, in order for west to east, are the Rouge Beach in Scarborough, Frenchman's Bay West Beach and East Beach located immediately adjacent to the Nuclear station,

proposed program

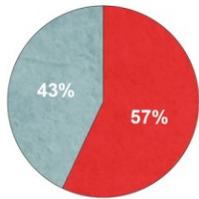
and Pickering Beach located just east of the station in Ajax [Fig.44]. Since 2009, these beaches have achieved a passing rate of 60-95% according to the Swim Guide.¹³⁸

A closer look at the quality of these beaches reveals that over the years since the Ontario Waterkeeper started collecting data, the water quality has shown improvement. This could be due to several factors, including water infrastructure improvement, decreasing precipitation levels, as well as collection inaccuracy.

138 Lake Ontario Waterkeeper. "Frenchman's Bay West Beach". The Swim Guide. www.theswimguide.org

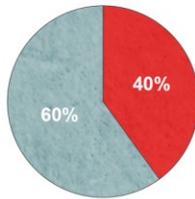
Fig. 44: Water Quality of Rouge Beach, Frenchman's Bay West & East Beach, Pickering Beach, 2009-2016. Data from www.theswimguide.org





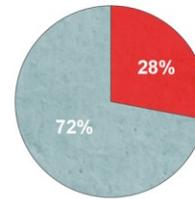
[2009]

| | | |
|------|------|------|
| Jun | N/A | |
| July | N/A | |
| Aug | 67%F | 33%P |
| Sep | 20%F | 80%P |



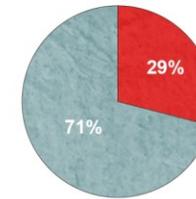
[2010]

| | | |
|------|------|------|
| Jun | 48%F | 52%P |
| July | 42%F | 58%P |
| Aug | 32%F | 68%P |
| Sep | 33%F | 67%P |



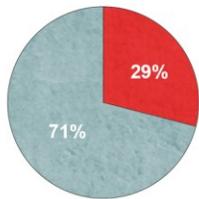
[2011]

| | | |
|------|------|------|
| Jun | 8%F | 92%P |
| July | 23%F | 77%P |
| Aug | 52%F | 48%P |
| Sep | 20%F | 80%P |



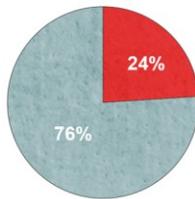
[2012]

| | | |
|------|------|------|
| Jun | 19%F | 81%P |
| July | 23%F | 77%P |
| Aug | 44%F | 56%P |
| Sep | 33%F | 67%P |



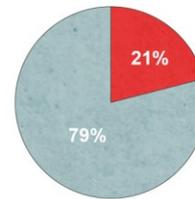
[2013]

| | | |
|------|------|------|
| Jun | 30%F | 70%P |
| July | 33%F | 67%P |
| Aug | 23%F | 77%P |
| Sep | 50%F | 50%P |



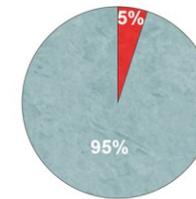
[2014]

| | | |
|------|------|-------|
| Jun | 18%F | 82%P |
| July | 21%F | 79%P |
| Aug | 33%F | 67%P |
| Sep | 0%F | 100%P |



[2015]

| | | |
|------|------|-------|
| Jun | 48%F | 52%P |
| July | 17%F | 83%P |
| Aug | 10%F | 90%P |
| Sep | 0%F | 100%P |

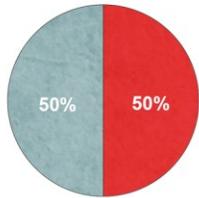


[2016]

| | | |
|------|------|-------|
| Jun | 0%F | 100%P |
| July | 12%F | 88%P |
| Aug | 5%F | 95%P |
| Sep | 0%F | 100%P |

Growth or Decay

Rouge Beach - Scarborough, Ontario



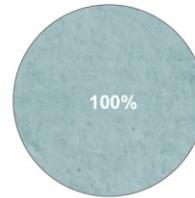
[2009]

| | | | |
|------|------|-------|--|
| Jun | N/A | | |
| July | N/A | | |
| Aug | 67%F | 33%P | |
| Sep | 0%F | 100%P | |



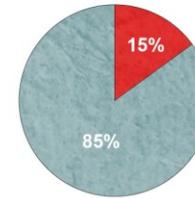
[2010]

| | | | |
|------|-----|-------|--|
| Jun | 0%F | 100%P | |
| July | 0%F | 100%P | |
| Aug | 0%F | 100%P | |
| Sep | 0%F | 100%P | |



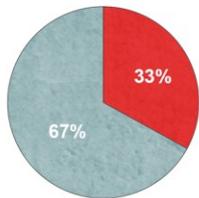
[2011]

| | | | |
|------|-----|-------|--|
| Jun | 0%F | 100%P | |
| July | 0%F | 100%P | |
| Aug | 0%F | 100%P | |
| Sep | 0%F | 100%P | |



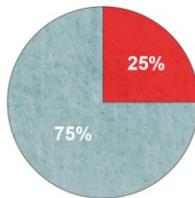
[2012]

| | | | |
|------|------|-------|--|
| Jun | 0%F | 100%P | |
| July | 6%F | 94%P | |
| Aug | 39%F | 61%P | |
| Sep | 0%F | 100%P | |



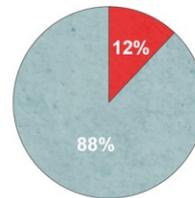
[2013]

| | | | |
|------|-------|------|--|
| Jun | 50%F | 50%P | |
| July | 23%F | 77%P | |
| Aug | 24%F | 76%P | |
| Sep | 100%F | 0%P | |



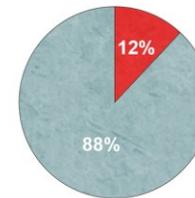
[2014]

| | | | |
|------|------|-------|--|
| Jun | 0%F | 100%P | |
| July | 0%F | 100%P | |
| Aug | 60%F | 40%P | |
| Sep | N/A | | |



[2015]

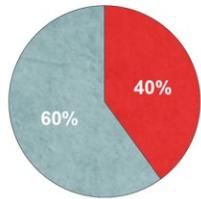
| | | | |
|------|------|-------|--|
| Jun | 42%F | 58%P | |
| July | 3%F | 97%P | |
| Aug | 0%F | 100%P | |
| Sep | 0%F | 100%P | |



[2016]

| | | | |
|------|------|-------|--|
| Jun | 25%F | 75%P | |
| July | 19%F | 81%P | |
| Aug | 0%F | 100%P | |
| Sep | 0%F | 100%P | |

Frenchman's Bay West Beach - Pickering, Ontario



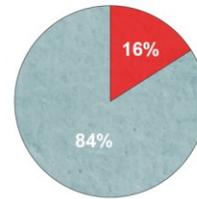
[2009]

| | | | |
|------|------|-------|--|
| Jun | N/A | | |
| July | N/A | | |
| Aug | 53%F | 47%P | |
| Sep | 0%F | 100%P | |



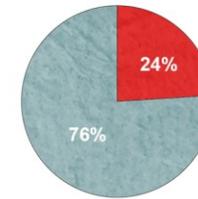
[2010]

| | | | |
|------|-----|-------|--|
| Jun | 0%F | 100%P | |
| July | 0%F | 100%P | |
| Aug | 0%F | 100%P | |
| Sep | 0%F | 100%P | |



[2011]

| | | | |
|------|------|-------|--|
| Jun | 0%F | 100%P | |
| July | 13%F | 87%P | |
| Aug | 32%F | 68%P | |
| Sep | 0%F | 100%P | |



[2012]

| | | | |
|------|------|-------|--|
| Jun | 0%F | 100%P | |
| July | 6%F | 94%P | |
| Aug | 55%F | 45%P | |
| Sep | 0%F | 100%P | |



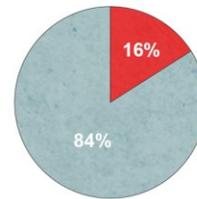
[2013]

| | | | |
|------|-----|-------|--|
| Jun | 0%F | 100%P | |
| July | 0%F | 100%P | |
| Aug | 0%F | 100%P | |
| Sep | 0%F | 100%P | |



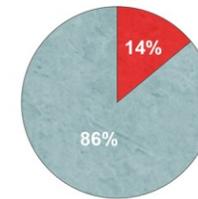
[2014]

| | | | |
|------|-----|-------|--|
| Jun | 0%F | 100%P | |
| July | 0%F | 100%P | |
| Aug | 0%F | 100%P | |
| Sep | 0%F | 100%P | |



[2015]

| | | | |
|------|------|-------|--|
| Jun | 42%F | 58%P | |
| July | 0%F | 100%P | |
| Aug | 0%F | 100%P | |
| Sep | 80%F | 20%P | |

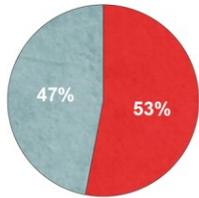


[2016]

| | | | |
|------|------|-------|--|
| Jun | 0%F | 100%P | |
| July | 37%F | 63%P | |
| Aug | 0%F | 100%P | |
| Sep | 0%F | 100%P | |

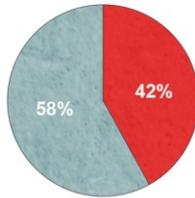
Growth or Decay

Frenchman's Bay East Beach - Pickering, Ontario



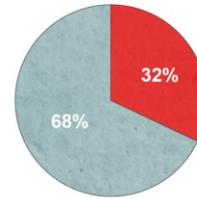
[2009]

| | | |
|------|------|-------|
| Jun | N/A | |
| July | N/A | |
| Aug | 67%F | 33%P |
| Sep | 0%F | 100%P |



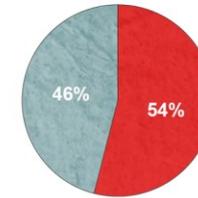
[2010]

| | | |
|------|------|-------|
| Jun | 0%F | 100%P |
| July | 74%F | 26%P |
| Aug | 42%F | 58%P |
| Sep | 14%F | 86%P |



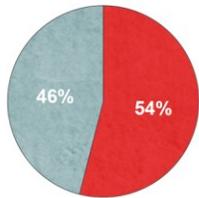
[2011]

| | | |
|------|------|-------|
| Jun | 0%F | 100%P |
| July | 35%F | 65%P |
| Aug | 55%F | 45%P |
| Sep | 0%F | 100%P |



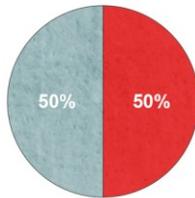
[2012]

| | | |
|------|-------|------|
| Jun | 26%F | 74%P |
| July | 52%F | 48%P |
| Aug | 77%F | 23%P |
| Sep | 100%F | 0%P |



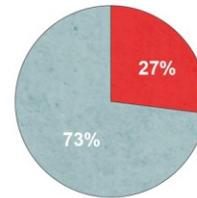
[2013]

| | | |
|------|-------|------|
| Jun | 55%F | 45%P |
| July | 64%F | 36%P |
| Aug | 40%F | 60%P |
| Sep | 100%F | 0%P |



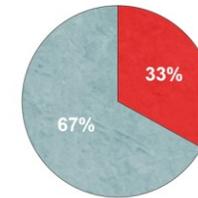
[2014]

| | | |
|------|------|-------|
| Jun | 33%F | 67%P |
| July | 0%F | 100%P |
| Aug | 92%F | 8%P |
| Sep | N/A | |



[2015]

| | | |
|------|------|-------|
| Jun | 37%F | 63%P |
| July | 50%F | 50%P |
| Aug | 0%F | 100%P |
| Sep | 0%F | 100%P |



[2016]

| | | |
|------|------|-------|
| Jun | 62%F | 38%P |
| July | 56%F | 44%P |
| Aug | 0%F | 100%P |
| Sep | 0%F | 100%P |

Pickering Beach - Ajax, Ontario

proposed program

Water Quality Issues

According to the Lake Ontario Waterkeeper, there are five issues which can have a negative impact on the lake's water quality:¹³⁹

Sewage bypasses: During heavy rain or rapid snow melt, wastewater can bypass the treatment plant, causing raw or partially sewage to enter our waterways. Under-treated sewage flows into Lake Ontario nearly every week year round in Toronto.

Combined sewer overflows: Combined sewers become overwhelmed during heavy rain and rapid

139 Lake Ontario Waterkeeper. "Protecting Toronto's Recreational Waters". <http://www.waterkeeper.ca/recwaterto/>

proposed program

snow melt, discharging wastewater and stormwater into our waterways.

Urban runoff: Runoff carrying sediment, pollutants and toxic chemicals is carried from urban centres through drains, sewers, and over pavement into our waterways. Runoff is a particular problem during heavy rain or snowmelt events.

Extreme weather: Extreme weather leads to more bypass events and increased runoff, releasing urban pollutants and sewage into our waterways.

Algae blooms: Algae blooms occur in the presence of nitrogen and phosphorus, harbouring bacteria and decreasing enjoyment of water activities.

proposed program

Algal Issues

One growing issue in the Great Lakes is the appearance of algae blooms. Algae are a natural part of the Great Lakes, but when certain conditions are present, such as high nutrient or light levels, these organisms can reproduce rapidly. Dense populations of algae are referred to as blooms, but not all blooms are harmless. A blue-green algae, scientifically known as cyanobacteria, is capable of producing a toxin which poses a threat to humans, animals, and fish.¹⁴⁰ These types of blooms are referred to as HABs, or harmful algal blooms [Fig.45].

Excessive algal growth can affect drinking water,



Fig.45: Lake Erie algal bloom. Source: www.dailymail.co.uk

Growth or Decay

140 Great Lakes Environmental Research Laboratory. "Harmful Algal Blooms in the Great Lakes". National Oceanic and Atmospheric Administration. www.glerl.noaa.gov

proposed program

recreational activities like swimming and fishing and shoreline property values. Human activities and the resulting nutrient enrichment, climatic warming, acidification and the spread of invasive species can all promote algal growth and worsen blooms.

Much of these algal blooms are a result of Phosphorus. Although it is naturally occurring and is an essential nutrient for all living organisms, if the concentration of phosphorus in surface waters is too high, it can lead to a proliferation of plant and algae growth that leads to reduced levels of oxygen in the water.¹⁴¹ This enrichment process -- called eutrophication -- can result in unsightly mats of algae. In extreme cases, low oxygen levels can

141 Kidd, Joanna. 2015 *Toronto and Region Remedial Action Plan Progress Report*. Toronto and Region Conservation Authority. www.torontorap.ca

proposed program

lead to the death of fish [Fig.46].

Total phosphorus concentrations have been declining throughout the Great Lakes since the 1970s as a result of remedial actions in Canada and the U.S. including legislative changes to reduce phosphorus loadings from waste water treatment plant effluent and other point sources.¹⁴² These improvements however, are proving to be inadequate according to studies out of the Town of Ajax.

One of the more nuisance algae in the Great Lakes is Cladophora. It requires four conditions in order to grow: sufficient light, a suitable substrate (or bottom) to attach



Fig.46: Eutrophication's effect on marine life.
Source: www.globalnews.ca

142 Kidd, Joanna. 2015 *Toronto and Region Remedial Action Plan Progress Report*. Toronto and Region Conservation Authority. www.torontorap.ca

proposed program

to, the right water temperature, and a food source (phosphorus).¹⁴³ During the summer of 2013, field work was carried out by a group led by Dr. Martin T. Auer, Professor of Civil & Environmental Engineering at Michigan Technological University, to uncover the relationship of cladophora growth and phosphorus outfall levels from the Duffin Creek Water Pollution Control Plant.

The study revealed that 98% of the bio-available phosphorus discharged directly to the Ajax-Pickering nearshore originates from the Duffin Creek WPCP.¹⁴⁴

The highest phosphorus concentration was observed in the immediate vicinity of the Duffin Creek WPCP outfall with

143 Auer, Martin T. "Field Studies of Phosphorus and Cladophora in Lake Ontario Along the Ajax, Ontario Waterfront". Town of Ajax. January 23, 2014. www.ajax.ca

144 Auer, Martin T. & Anika Kuczynski. *Phosphorus, Cladophora and the Ajax Nearshore*. Great Lakes Research Center. www.ajax.ca

proposed program

levels decreasing with distance from that location [Fig.47].¹⁴⁵

Following these studies, the Ministry of the Environment and Climate Change has become involved; meeting with several proponents and experts to push for a WPCP Phosphorus Reduction Action Plan. They are currently completing further study, as well as exploring several options for remediating the problem.

Co-optimized Systems

The issues at the Duffin Creek WPCP come at an interesting time as the Pickering Nuclear station's lifecycle comes to an end. Both of these properties occupy a large

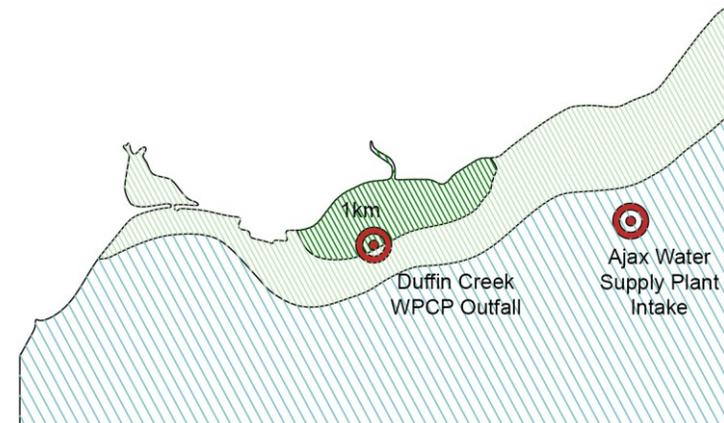


Fig.47: Duffin Creek WPCP Outfall.

145 Auer, Martin T. *Field Studies of Phosphorus and Cladophora in Lake Ontario Along the Ajax, Ontario Waterfront*. Town of Ajax. January 23, 2014. www.ajax.ca

proposed program

section of Pickering's waterfront, which is some of the most desirable land in the city. As the city's population is expected to grow, more strain will be placed on the existing WPCP, which will need to expand to accommodate such an increase in intake. This could offer a potential opportunity for "Resource Co-optimization", a term introduced by Bry Sarté and Morana Stipisic in their book titled *Water Infrastructure: Equitable Deployment of Resilient Systems*. Resource co-optimization occurs where more than one traditional infrastructural objective is achieved through integrated design synergies.¹⁴⁶ The focus of this strategy is to combine one or more systems of infrastructure with a water system to expand benefits,

146 Sarté, S. Bry and Morana M. Stipisic. *Water Infrastructure: Equitable Deployment of Resilient Systems*. Columbia University, New York, New York. 2016. Pg. 62.

proposed program

cost sharing, and performance.

As the cost of infrastructure continues to rise, innovation is required to produce multiple resource flows with single investments. Energy and waste resource systems can be combined with water infrastructure to increase performance. Additionally, water infrastructure systems that are usually separated can be managed in conjunction with one another to increase mutual benefits (i.e. combining recycled water with storm water for non-potable use).

Current infrastructure at the Duffin Creek WPCP utilizes aged practices, relying on settling ponds and surface aerators. These practices can occupy a lot of space, and

proposed program

are not as efficient as new water treatment technologies. Current technologies are designed to capture waste nutrients as a resource to be reused as fertilizers, fuels, and electricity, or to generate excess utility capacity, providing potential financial benefits.

One of the more promising innovations is an invention called the "Omniprocessor"[Fig.48]. You may have heard of this invention with reference to headlines which read "Bill Gates drinks water distilled from human faeces". This invention does just that, it creates pure distilled water from human waste; while at the same time producing sellable fertilizer pellets and producing enough electricity in the process to power the machine, as well as creating a surplus of energy to be used in the surrounding



Fig.48: Janicki Omniprocessor. Source: www.wikipedia.com

proposed program

community.

The Omniprocessor was developed by Janicki Bioenergy, an engineering firm based north of Seattle, Washington, and is backed by the Gates Foundation. The idea behind the invention was to "reinvent the sewage treatment plant",¹⁴⁷ as current treatment plants burn the waste using diesel or other fuel that they have to purchase, meaning they use a lot of energy, rather than producing their own.

The Omniprocessor solves that problem through the use of a steam engine, which produces enough energy to power itself, with electricity to spare. The current Omniprocessor can handle waste from 100,000 people,

147 Gates, Bill. "This Ingenious Machine Turns Feces Into Drinking Water". GatesNotes. January 5, 2015. www.gatesnotes.com

proposed program

producing 86,000 liters of potable water per day and a net 250 kilowatts of electricity.¹⁴⁸

Implementation of these strategies could present opportunities to include low/no energy infrastructure into the grid. Possibly of greatest importance is the ability to create dynamic self-sustaining public spaces that enrich the environmental and social context of the Pickering waterfront.

Water Filtration

Updated practices in water remediation are currently replacing older systems around North America. Not 30 kilometers from the Pickering site, is the East Bayfront

148 Gates, Bill. "This Ingenious Machine Turns Feces Into Drinking Water". GatesNotes. January 5, 2015. www.gatesnotes.com

proposed program

redevelopment project, situated between Lakeshore Boulevard and Lake Ontario from Jarvis Street to Parliament Street in Toronto. The finished project will contain 6000 residential units, employment for 8000 people, 3 000 000 square feet of commercial space and 5.5 hectares of open spaces and parks.¹⁴⁹

At the heart of East Bayfront is Sherbourne Common[Fig.49], a 1.5 hectare park which fully opened in 2011. The park serves as a public amenity and central gathering area for the new vibrant mixed-use community, as well as a unique visible showcase for the integration of infrastructure into the public realm.¹⁵⁰



Fig.49: Sherbourne Common water feature. Source: www.wsj.com

149 The Municipal Infrastructure Group Ltd. *Sherbourne Common*. May 8th, 2012. www.canadianconsultingengineer.com
150 Ibid.

proposed program

The design incorporates a pumping station and ultra-violet (UV) disinfection system that forms an integral part of the community stormwater management strategy. The extent of stormwater management treatment that occurs in Sherbourne Common is the next stage in the evolution of stormwater management technology. Trojan Technologies has supplied and installed two TrojanUVFit reactors at the UV facility. The reactors have the capacity to treat stormwater at a rate of 70L/s or 1.6 million gallons per day each.¹⁵¹

Notwithstanding the small scale of lake water treatment relative to the size of the lake, the approach of Sherbourne

151 Water Technology. *Sherbourne Common Stormwater Treatment Facility*. www.water-technology.net

proposed program

Common is that of a catalyst for the development of similar solutions that, together, can at a broader scale address the impacts of urbanization on our significant water assets.¹⁵²

The Sherbourne Commons approach to water treatment, in terms of amounts, is on the lower side of the spectrum, but Trojan Technologies does provide systems for larger scale water treatment. For example, they have provided the Little Blue Valley Sewer District (LBVSD) in Missouri, US, with their Trojan UVSigna open channel wastewater ultraviolet light disinfection system[Fig.50]. This system was designed for large-scale wastewater disinfection applications, and will disinfect an average of



Fig.50: Trojan UVSigna ultraviolet light disinfection system.
Source: www.trojanuv.com

152 The Municipal Infrastructure Group Ltd. *Sherbourne Common*. May 8th, 2012. www.canadianconsultingengineer.com

proposed program

52 million gallons of water per day, with a peak capacity of 150 million gallons of water per day.¹⁵³

This type of system aligns with the aims of the thesis design for a large scale water treatment project. What is even more promising is that this system is already half a decade old, and in a few decades from now, water treatment systems will have improved even further.

It is imperative to incorporate green infrastructure and high performance ecology into the urban fabric to sustain healthier communities, and improve quality of life; as improving ecological health supports human health.

153 Water Technology. *Trojan Technologies to supply wastewater disinfection system to LBVSD*. October 10, 2011. www.water-technology.net

proposed program

Urban Agriculture

"The separation of cities from their food sources is directly linked to many of the most pressing problems in the world today -- including climate change, obesity, pollution, security of the energy supply, and global poverty."¹⁵⁴ In their book *Carrot City: Creating Places for Urban Agriculture*, Mark Gorgolewski, June Komisar and Joe Nasr discuss how the current practice of food production is disengaged from the communities it feeds. They raise concerns about current commercial food systems and link them to damage caused to the natural environment, low nutritional quality, and high energy

¹⁵⁴ Gorgolewski, Mark, June Komisar & Joe Nasr. *Carrot City: Creating Places for Urban Agriculture*. The Monacelli Press, a division of Random House, Inc. New York. 2011. Pg.13.

proposed program

consumption necessary for the transportation of food long distances.

These issues are becoming more urgent every day as food is becoming less affordable. Even in the richest countries, food security is an issue. According to the most recent data by Statistics Canada, 12.7% of Canadian households experienced some food insecurity in 2012;¹⁵⁵ an increase from 11.3% in 2007-2008.¹⁵⁶ The inadequate or insecure access to food due to financial constraints is a serious public health problem. It negatively impacts physical, mental, and social health, as well as increases costs for our healthcare system.¹⁵⁷

155 PROOF: Food Insecurity Policy Research. "Food Insecurity in Canada". www.proof.utoronto.ca

156 Ibid.

157 Gorgolewski, Mark, June Komisar & Joe Nasr. *Carrot City: Creating Places for Urban Agriculture*. The Monacelli Press, a division of Random House, Inc. New York. 2011. Pg.13.

proposed program

With a current world population of about 7.3 billion and predicted to grow to 9.7 billion by 2050,¹⁵⁸ modifying what we eat, how we produce it, and where it comes from is a necessity to combat climate change. By reducing the distance between producer and consumer, urban agriculture can lessen energy use. Moreover cooking from basic, fresh ingredients is less carbon-intensive than cooking with highly processed foods.

In a world where food supplies are increasingly difficult to guarantee, food is expensive to produce, and shipping methods are detrimental to the environment. In the near future, locally based food systems will be essential to a

158 United Nations Department of Economic and Social Affairs. "World population projected to reach 9.7 billion by 2050". United Nations. July 29, 2015. www.un.org

proposed program

city's resilience. Growing food in cities reduces the dependency on distant food supply chains that can be disrupted for any number of reasons.

Apart from enhancing food security and reducing our ecological footprint, urban agriculture can also play a role in greening cities, which benefits water management, air quality, and social programs. A central question is how best to connect the food system to other nutrient systems in the city.

A complete or ecologically sustainable design for a city would be a closed loop system, with all the wastes from one process used as an input to another process. Urban agriculture has a large role to play in closing open,

proposed program

polluting loops in the nutrient cycle. Designers are now beginning to propose built-environment patterns that address the urban food cycle and offer responses to the problems in urban resource and nutrient cycles.

DECOMMISSIONING PICKERING

As discussed in the chapter on decommissioning, the international best practice for disassembly of a nuclear power station is that of *Immediate Dismantling* (See Pg. 73). This strategy applies to facilities which have not incurred any serious releases of nuclear radiation.

With the available information disclosed to the public, historical evidence shows that Pickering's accidents, though severe on several occasions, have not had any incidences of severe nuclear radiation released within the reactor containment structures, as well as off-site.

It is with this knowledge that an important question to ask is, would it be beneficial to preserve these buildings in the decommissioning plan? Although the community would agree that the Pickering Nuclear Station is an eyesore, there are architectural qualities to some of the built infrastructure that if preserved, could prove to be invaluable.

In an excerpt from his book *Greening Modernism: Preservation, Sustainability, and the Modern Movement*, Carl Stein discusses how the conservation of existing buildings is also a best practice for decommissioning:

decommissioning pickering

"There are many measurable benefits to preservation, including reduced energy use, carbon release and landfill material. There is also quantifiable job creation, which is greater per dollar spent for renovation than for new construction. There are also qualitative benefits, including community preservation and reinforcement of sense of place. Buildings and sites that are important cultural and historical artifacts must be preserved for their iconic and symbolic significance regardless of other considerations. The authentic historic value cannot be re-created in new construction, regardless of economic or environmental expenditure."¹⁵⁹

Although many find the Pickering Nuclear Station to be drab, it has great historical significance for Pickering, as well as the Country. To construct such a grand endeavor

159 Stein, Carl. *Greening Modernism: Preservation, Sustainability, and the Modern Movement*. 2010. Pg. 83.

decommissioning pickering

was a historical feat for Canada, and to completely eliminate the memory of this landmark would be a lost opportunity.

There are several buildings on-site, from the reactor buildings and turbine halls, to administration and dry-storage hangars [Fig. 51]. The buildings that hold the most architectural significance are the concrete buildings, i.e. the eight reactor buildings and the vacuum building [Figs. 52 & 53]. These buildings offer the possibility of adapting to new program operations and are durable enough to last several more decades. However, as evidence suggests, it is quite possible that the interior of the reactor buildings could require an extensive rest period (50 years, see Pg. 70) for radiation levels to decay



Fig.51: Existing buildings on-the Pickering site.

decommissioning pickering

to safe levels. This is not to say that a new development could not be constructed around it in the meantime, in fact deconstructing and recycling most of the other buildings on site could be easily completed as they are simple steel frame structures.

Once all of the contaminated components from the reactors as well as the turbine hall are all dismantled and placed in permanent storage, the turbine building could be deconstructed as well, leaving the reactors to stand freely.

Although one could argue to keep all of the buildings as a more sustainable approach to dismantlement, the reality is that the site was designed in an industrial fashion with

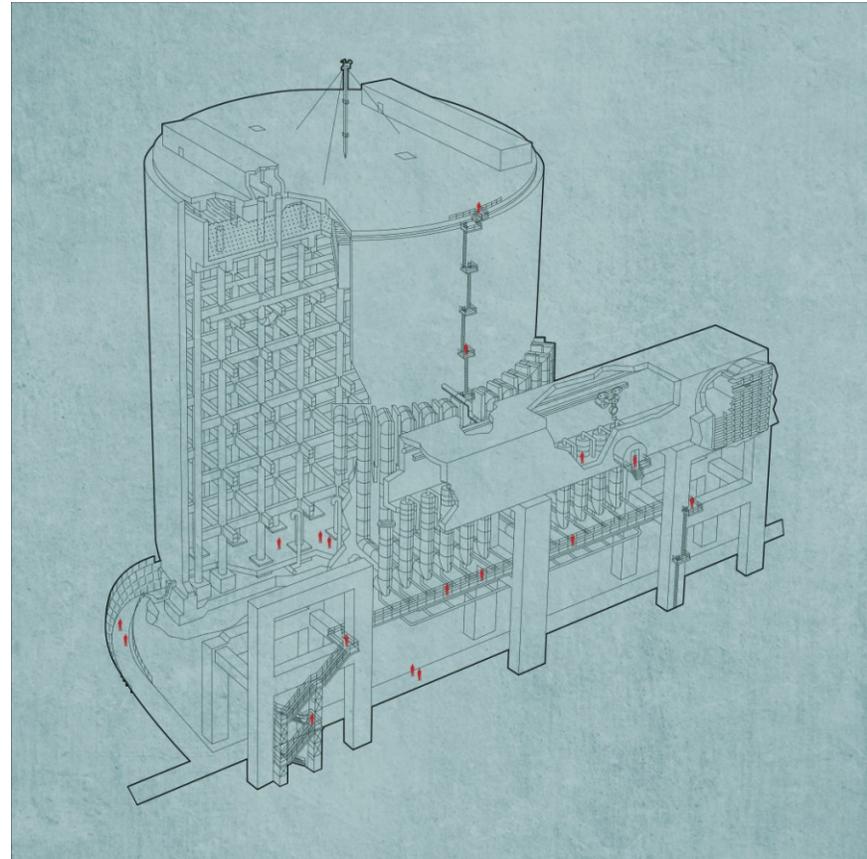


Fig.52: Axonometric reveal drawing of the Pickering vacuum building.

decommissioning pickering

the primary focus on energy production and security. A new design accommodating public interaction and intimacy could prove to be much more beneficial. As we progress, it is also important to note that building material recycling has become quite efficient, as we recognize that resources are finite, material recycling will become quite important for humanity.

Timeline

The following pages demonstrates a potential timeline for both the decommissioning and construction of the site.

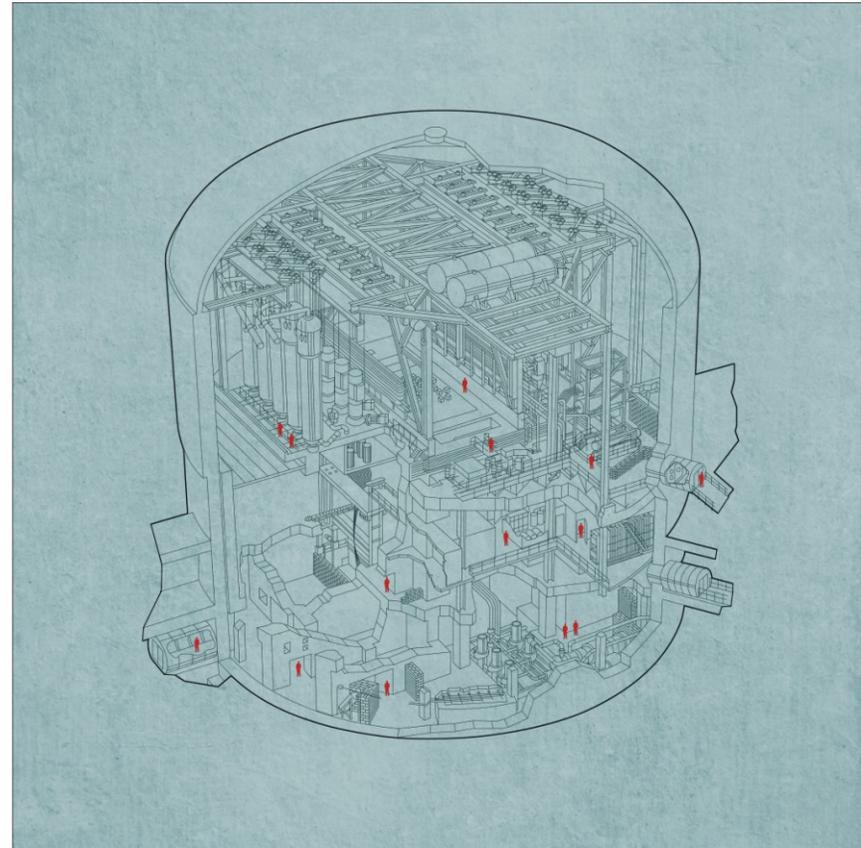
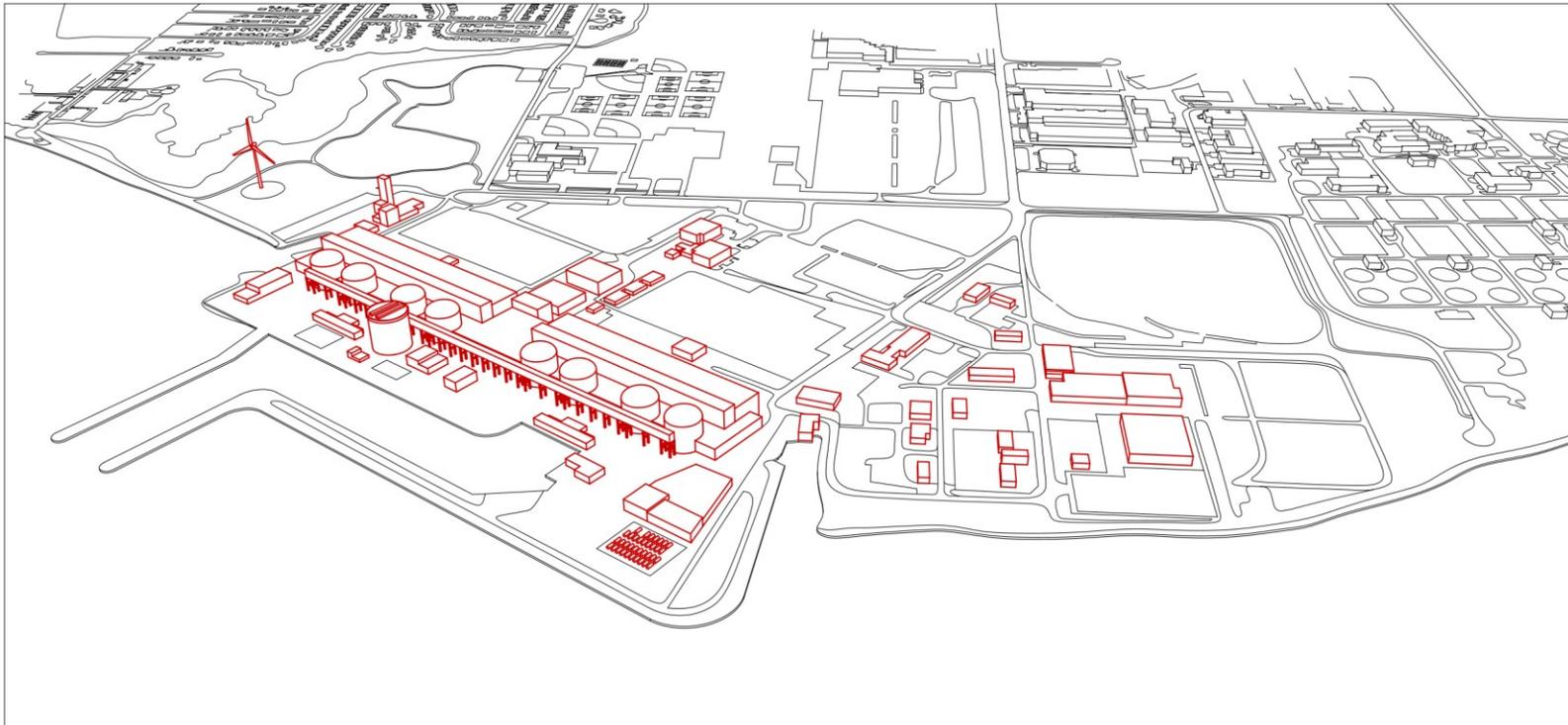


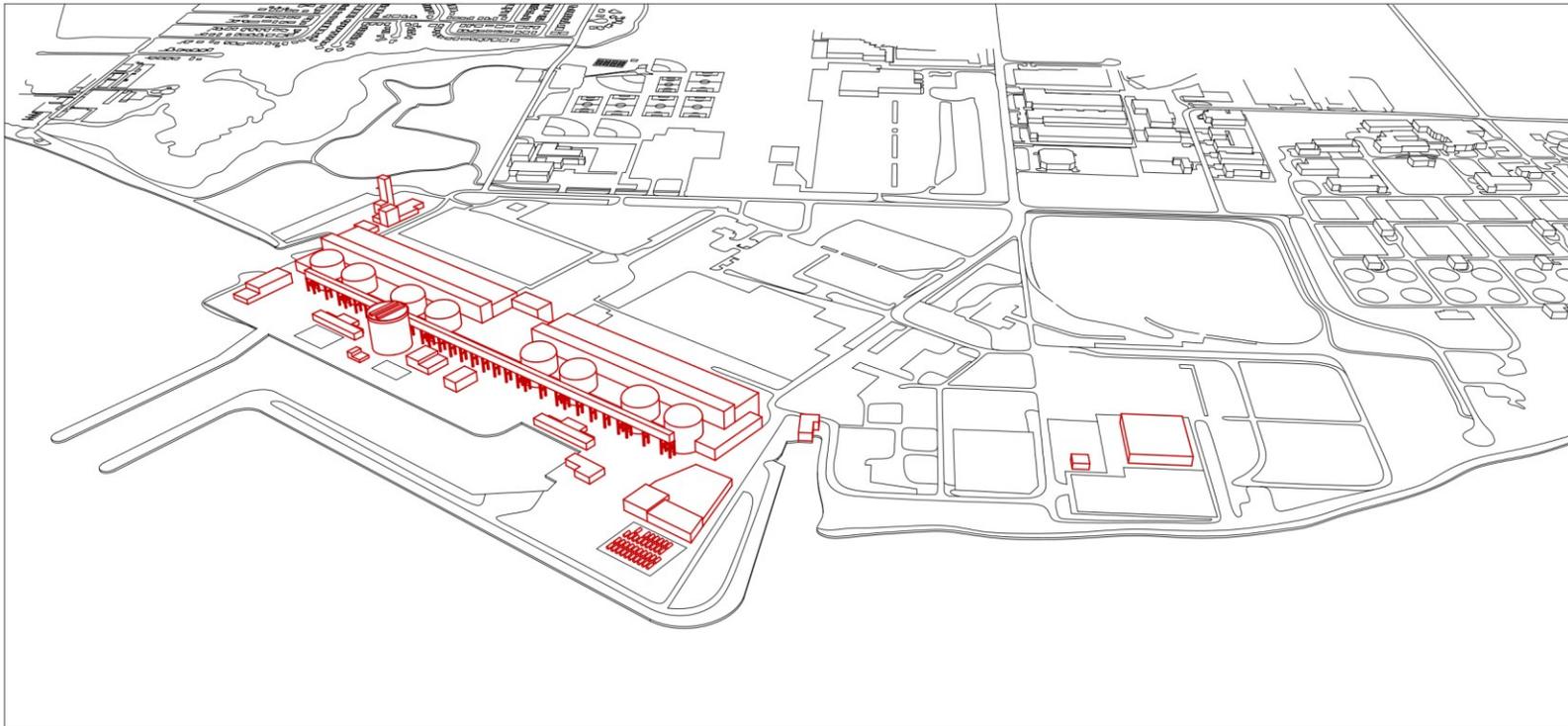
Fig 53: Axonometric reveal of a Pickering CANDU reactor building.

Fig.54: Decommissioning timeline for the Pickering Nuclear Site



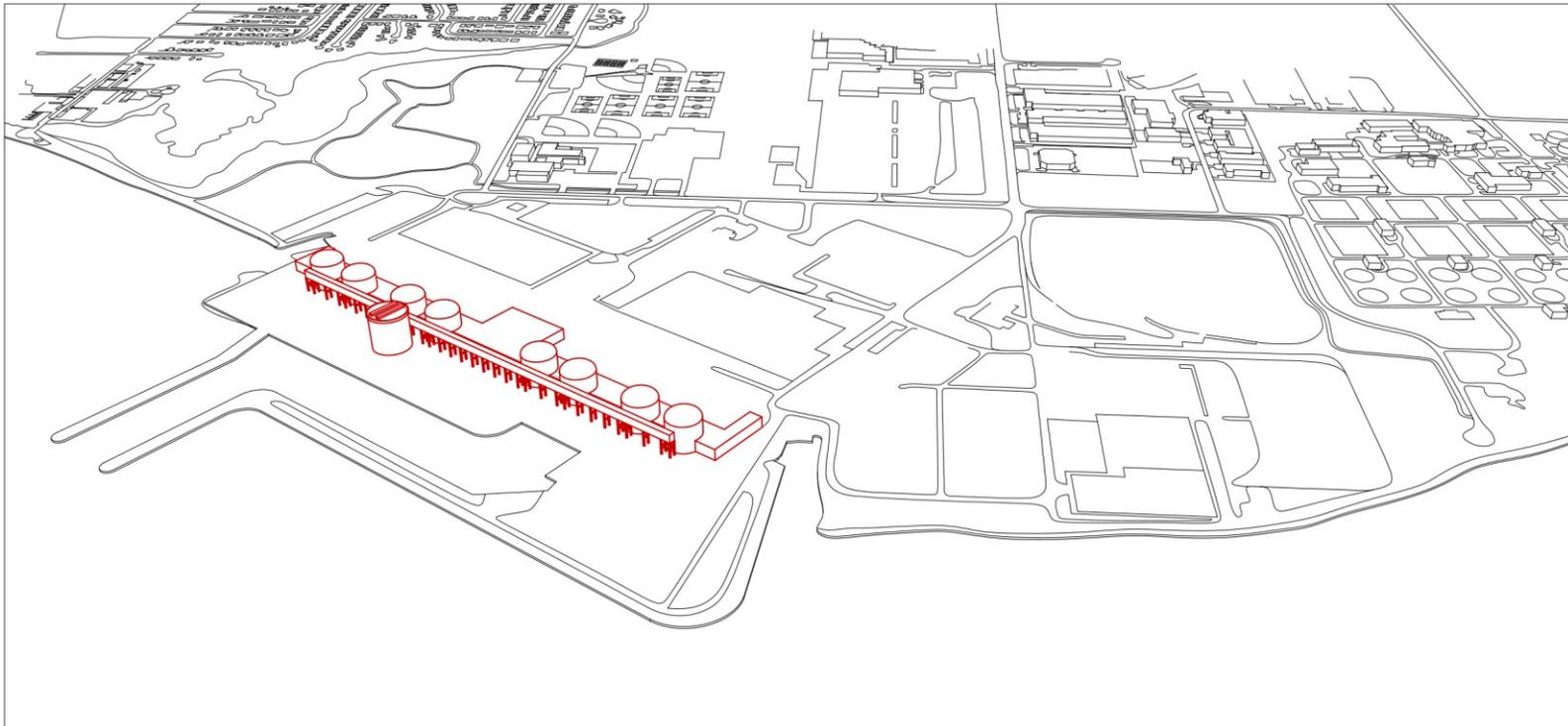
1) The Shutdown of the Pickering Nuclear Generation Station. 2024.

The end of commercial operations for all Pickering reactors. Preparations for decommissioning of the station, as well as Safe storage activities, can begin.



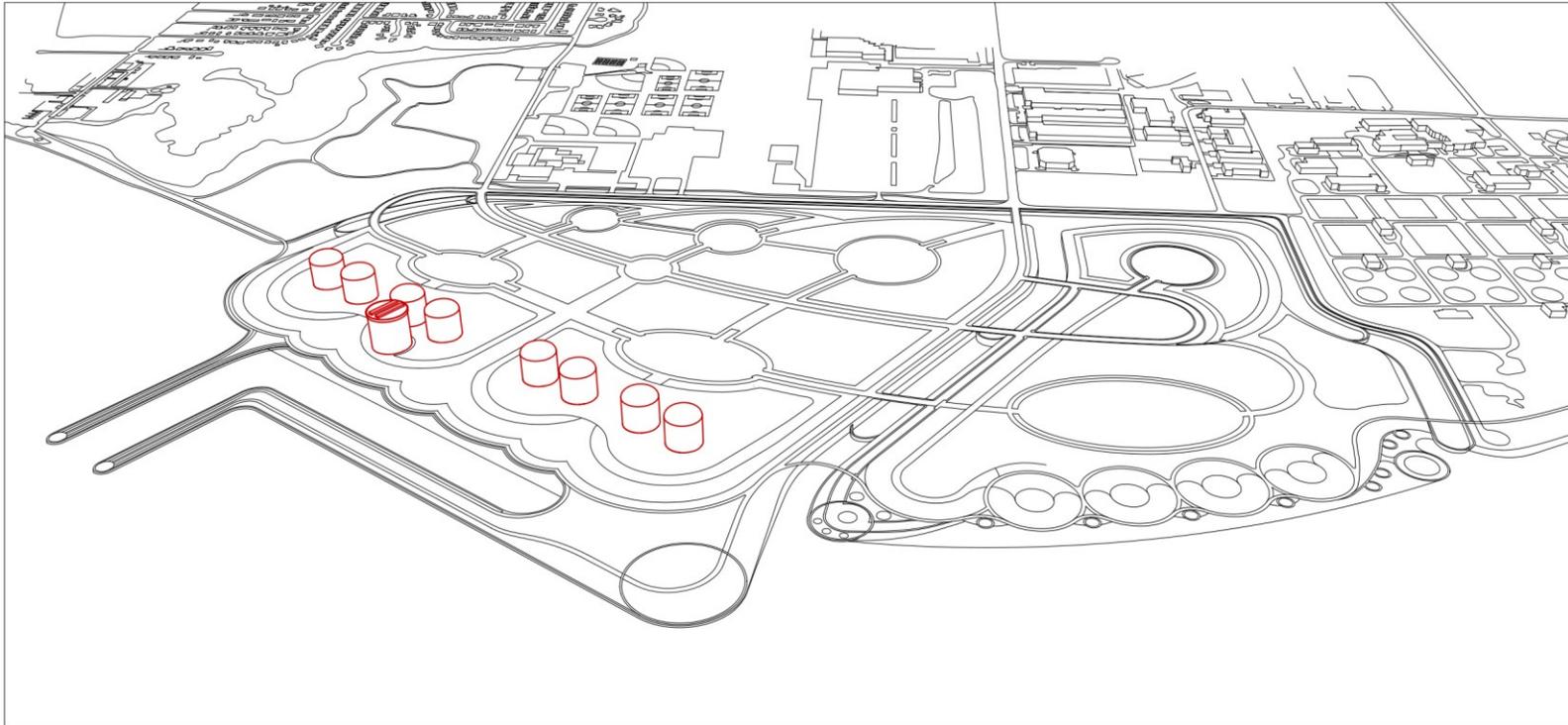
2) All Used Fuel Transferred to Dry Storage. +13 years.

During the first 10 years of safe storage, used fuel will be transferred into dry storage containers and moved to the adjacent waste management facility. During this time all non-essential buildings can be dismantled.



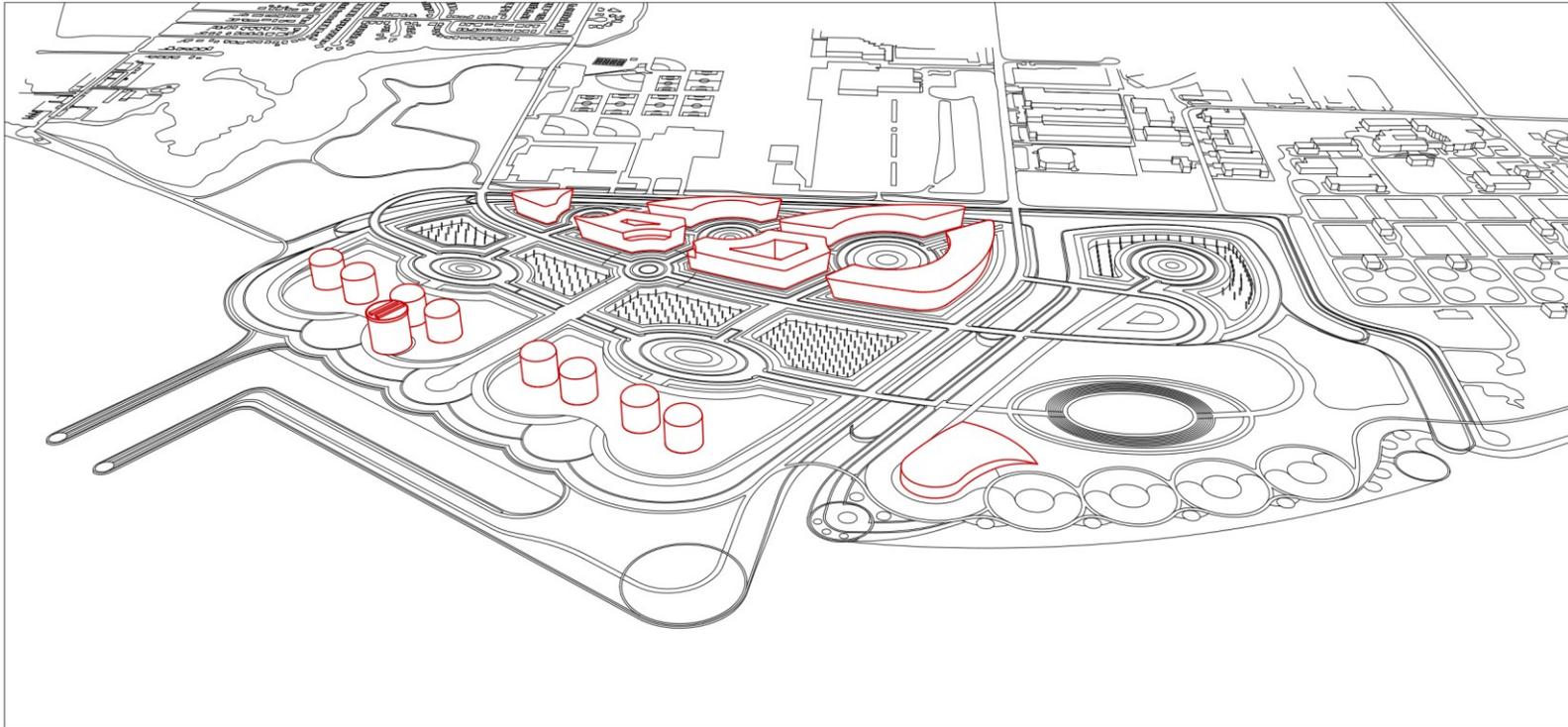
3) Site Deconstruction & Removal of All Contaminated Materials. +15-16 years.

All used fuel containers are moved to a permanent storage facility off-site. Deconstruction of storage hangers and the turbine hall. Site construction can begin.



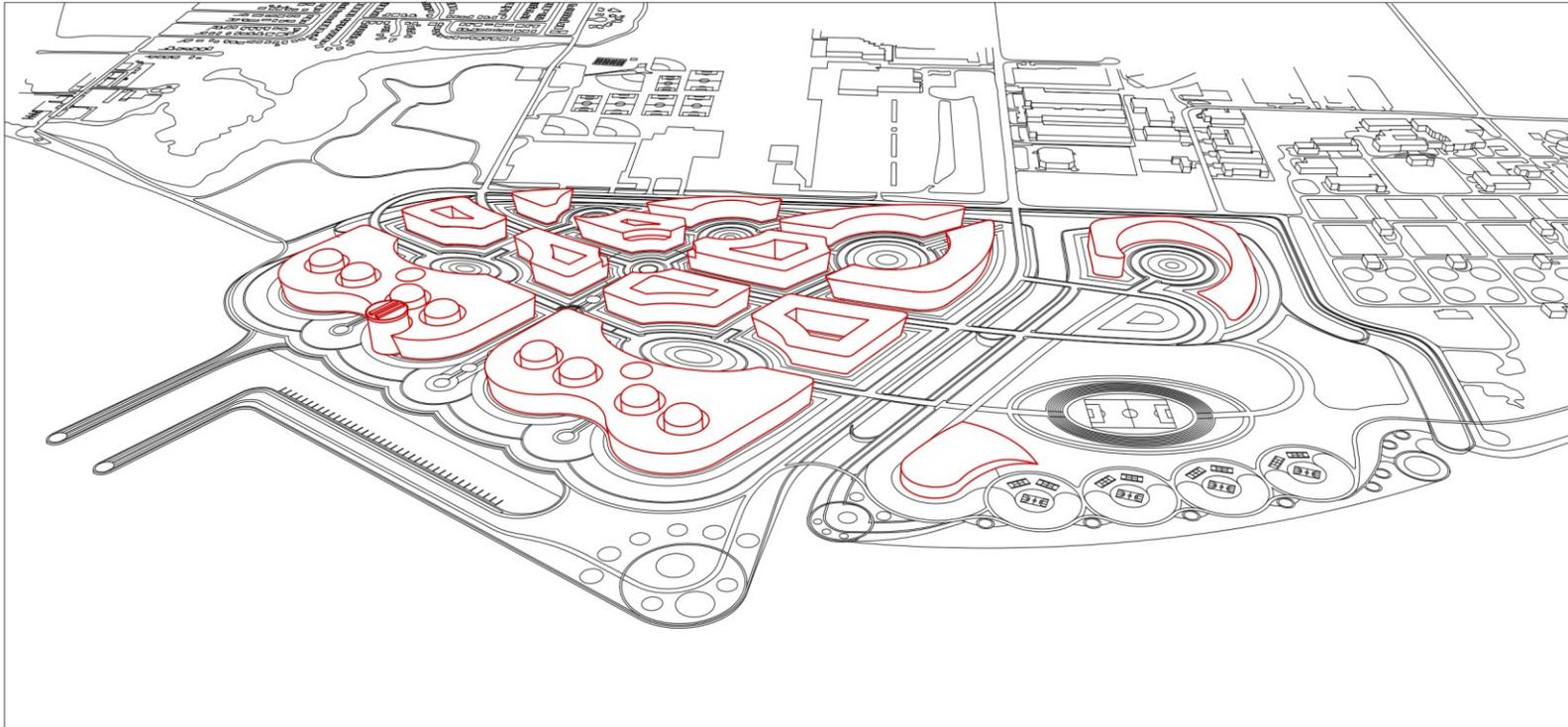
4) Construction of Canals and Site Preparation. +18-19 years.

At this point, the decommissioning of the nuclear facilities will be complete and construction of the canal system is near completion. The site has been laid out for construction of the new buildings.



5) Construction of New Buildings. +20-25 years.

The canal system is completed and construction of new buildings is approaching completion.



6) Site Fully Open to Public. +25-30 years.

Both public and private activities have begun. At this point the reactor buildings are halfway through the 50 year safe storage period.

THE PROPOSAL

There were several factors which contributed to this design strategy, as well as some limitations which directed the focus away from certain characters on-site. The main factor being that the Pickering Nuclear Generating Station is a highly restricted facility; meaning that the site, as well as all of its technical information and drawings are inaccessible to the general public. With this limited information, and the knowledge that the reactor buildings will need upwards of 50 years to become available for new program, the direction of the project was aimed towards an alternative design strategy which would surround these buildings -- leaving them to decay, while the site would continue to grow.

It is here that the title of this thesis truly unfolds. The title suggests only two choices -- that of growth, or of decay -- instead I have chosen a third choice, both. The two choices represent polar sides of the current decommissioning argument; whereas "growth" represents the immediate decommissioning of the site to a greenfield state, and "decay" represents the current OPG plan to let the facility remain on site for several decades.

By choosing a combination of the two, this will allow the site to retain its architecture of historical significance, -- i.e. the large vacuum and reactor buildings -- while transforming into new public space capable of responding to the needs of the future populace.

the proposal

The main design concept was the idea of adaptability. As a species, humankind demonstrates itself to be the most adaptable on the planet, so why should our built infrastructure not share this quality?

The design was primarily focused around our most essential resource: water. Due to its adjacency to Lake Ontario, the Pickering site offers an ideal solution for water utility infrastructure. Also, because of its' neighbouring to the Duffin Creek WPCP, therein lies the opportunity to combine efforts in water treatment. However, due to the fact that the adjacent Duffin Creek WPCP is municipally controlled and operated, the new

the proposal

site design only transforms the private land owned by OPG that would be released following the decommissioning of the site. The prospect would be that the new design proposal would instigate the desire from the municipality to update the WPCP's current systems and site design to open more lakefront to the public. But, for now the only water treatment on site would be lakewater and stormwater remediation.

The problem with current water treatment operations is that during heavy rainfalls, sewer systems can be forced to discharge untreated or partially treated sewage into the lake. This is what leads to beach closures, as seen in Fig.44[Pg.127-131]. The untreated sewage can result in damage to ecosystems as well as force beachgoers to

the proposal

remain on-shore during the hot summer months, as water quality levels can remain unsafe for several days after a heavy rainfall.

To help remediate this situation, the design incorporates a series of canals which both divide and form the perimeter of the site [Fig.55]. The placement of the canal at the periphery allows it to collect stormwater from the surrounding area. This design characteristic is also reference to the existing site; where there once was barbed wire fence to keep people out, now stands a 'moat-like' canal acting as the new threshold to the public entering the site.



Growth or Decay

Fig.55: Proposed site plan for the Pickering site.

the proposal

The water system would rely on three pumping stations [seen in Fig.56] to draw in lakewater (or in the case of a storm, stormwater), to be treated with UV systems like that of Trojan Technologies. Once treated, the collected water will be distributed to the canal and several remediation pools around the site; further purifying the clarified water through biofiltration. This filtrated water has different release points around the site; situated mainly around areas designated for water activities like the new beachfront, as well as the hardscaped swim area just south of the reactors.

Two out of the three pumping stations provide the majority of the filtration for the site, with the west



Fig.56: Water intake and outflow diagram.

the proposal

pumping station designated for the possibility of water remediation for Frenchman's Bay; an important body of water to maintain for the local ecosystem.

To accommodate the amount of filtered water distributed from the pumping stations, the canal had to be able to hold large quantities of water. The metric equivalent to the LBVSD system in Missouri of 52 million gallons of water per day is 196 841 413 liters, therefore the canal was designed for a volume of over 500 million liters; which is close to the peak capacity of the LBVSD system of 150 million gallons of water per day.

The canal system itself could operate several different

the proposal

program concurrently, or at separate times when certain program are needed more. These program could include, but are not limited to: lakewater remediation, stormwater capture and remediation, and aquaculture* .

The canal would be able to operate solitarly with the future incorporation of artificial intelligence into human practices. This would mean that it could immediately adapt to the changes needed by the populace. For example, in the event of heavy precipitation, sections of the canal could expel their treated water to accommodate for the collection of the forecasted rainfall. Once collected, the stormwater would be purified through mechanical and natural processes, to then be released to the lake once it has

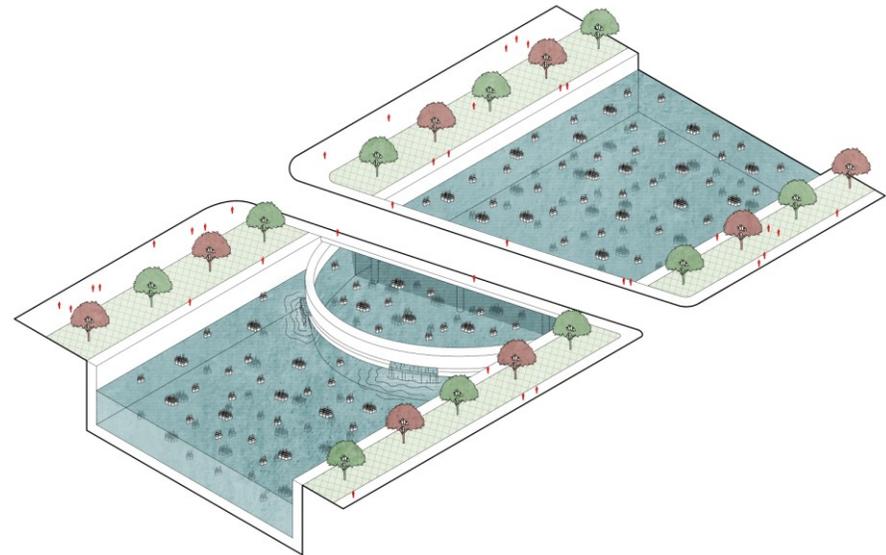


Fig.57: Canal axonometric view.

the proposal

achieved absolute purification standards.

The design incorporates several other remediation pools throughout the site. These pools receive remediated water from the mechanical infrastructure housed on-site, and assist in adding nutrients to the water with riparian vegetation. Once the water in these pools has reached their required purification standard, it is released into the lake, providing safe, clean lakewater for the waterfront.

The pools are centrally-placed within constructed courtyards. Each pool offers space for leisure and relaxation for guests as well as the many employees that would work here throughout the day. It is even

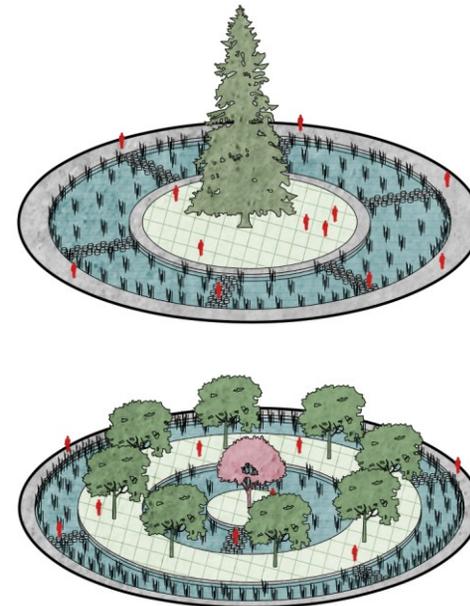


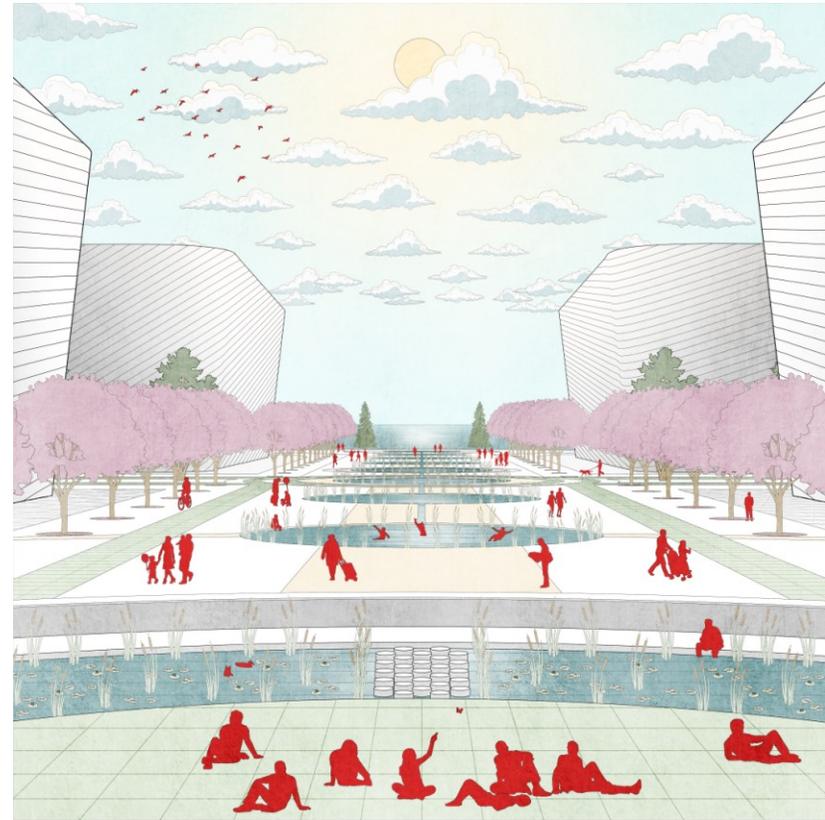
Fig.58: Remediation Pools.

the proposal

possible that many of these pools could be swimmable [Fig.59], offering a natural-pool to refresh in during the upcoming hot summer months.

The site would be accessible from Sandy Beach Road and Brock Road; with Montgomery Park Road spanning the northern border of the site and providing another entrance on the West side for the more private programs (i.e. electrical).

The movement through the site is meant to facilitate vehicle movement with the use of roundabouts surrounding the many remediation pools around the site. There are roughly 320 parking spaces on the surface of the site, with additional opportunities for



Growth or Decay

Fig.59: The central axis which incorporates eight remediation pools.

the proposal

parking underground. There are several entrances for vehicles to the underground level, as these would also be utilized for the shipping and receiving of goods to and from the many buildings on site. These entrances are each placed within the courtyard roundabouts between the buildings.

With the implementation of self-driving cars already today, parking will have become quite perfected after a couple decades. One of the main issues with parking today is the distances many people have to walk to their destination after having parked in the furthest corners of parking lots. With self-driving cars, it will be possible for visitors to be dropped off directly outside their desired location (i.e. the new community

the proposal

center, sports field, or beach), afterwards the vehicle would park itself in an available parking space; while also being able to return to the desired location of the vehicle owner on desired pick-up.

The site is divided into two parts, with the larger section housing most of the buildings which would house the energy and water infrastructure, as well as ample space for other program including agriculture and education. Due to the incorporation of several large industry sectors on-site, there is great opportunity here for a hands-on educational system for the energy, water, and agriculture sectors. In the coming future, many people will lose their jobs to automation. Educational reform will be needed in these large

the proposal

sectors to accommodate this loss.

The right side of the site offers more public space, with the added opportunity for a residential building to be implemented. This portion also offers a community centre closest to the lake and 'hilled' areas for tobogganing during the winter months. One of the main features in this section is the sports field [Fig.60]. The field is dropped below grade to create an outdoor-stadium-like effect. Surrounding the field is the largest remediation pool on-site, with water that streams down from the upper most level, until it reaches the base and is directed out to the lake. The outdoor stadium could offer space for over a thousand viewers.

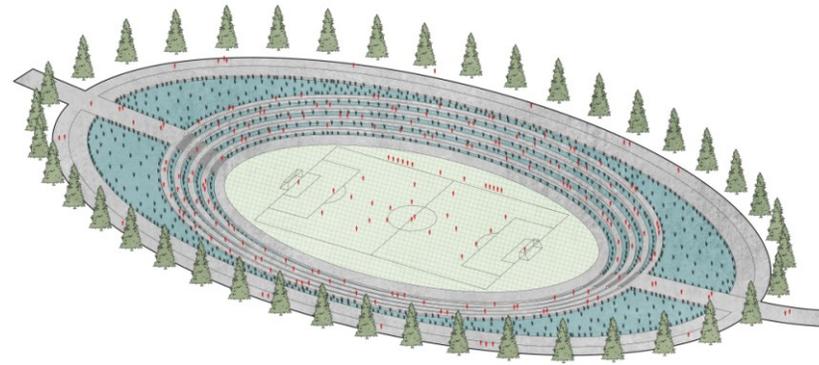


Fig.60: Outdoor stadium with surrounding remediation pools.

the proposal

As a sort of pilot project, I have also included a concept design of a filtration system that could be designed and manufactured on-site [Fig.61]. With the introduction of the canals, maintenance of its condition plays an important role in its efficacy, therefore, they must be able to manage debris easily. This results in a dry bottom, free of organic matter to facilitate the removal of any fallen debris that may enter the canals.

To implement a natural filtration system within the canals without any organic matter to plant riparian vegetation was a design issue. To respond to this problem, a series of "floating filters" would be dispersed throughout the canals -- or in the sections

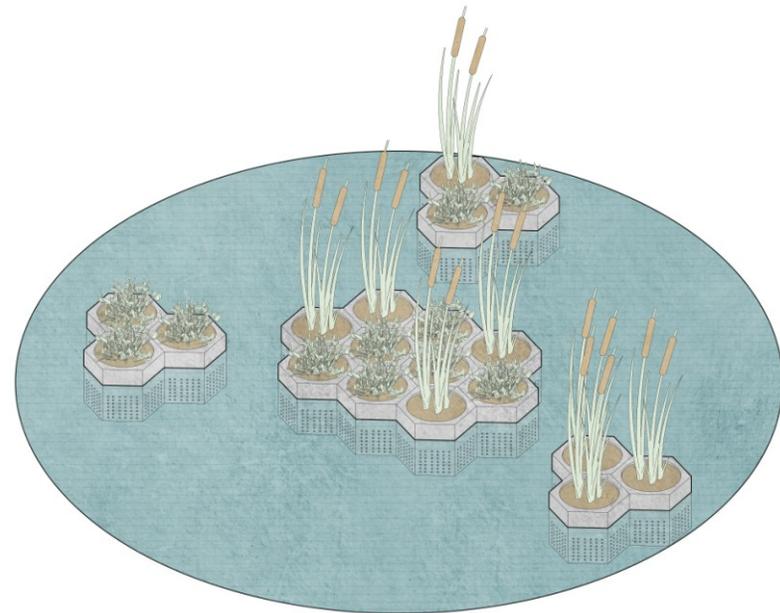


Fig.61: "Floating Filters".

the proposal

designated for water remediation [Fig.62]. These filters are designed utilizing a hexagonal base as a modular system. The base's six sides are all porous to allow water to pass through and engage with the soil and root structures of the plants within.

Energy Production

The original design of the Pickering Nuclear Station was oriented to true north, and so this axis was continued in the new design. This direction also benefits the application of photovoltaic panels. For a unified system to work here, it is important that these buildings would be self-sufficient and are able to produce enough electricity for themselves. According

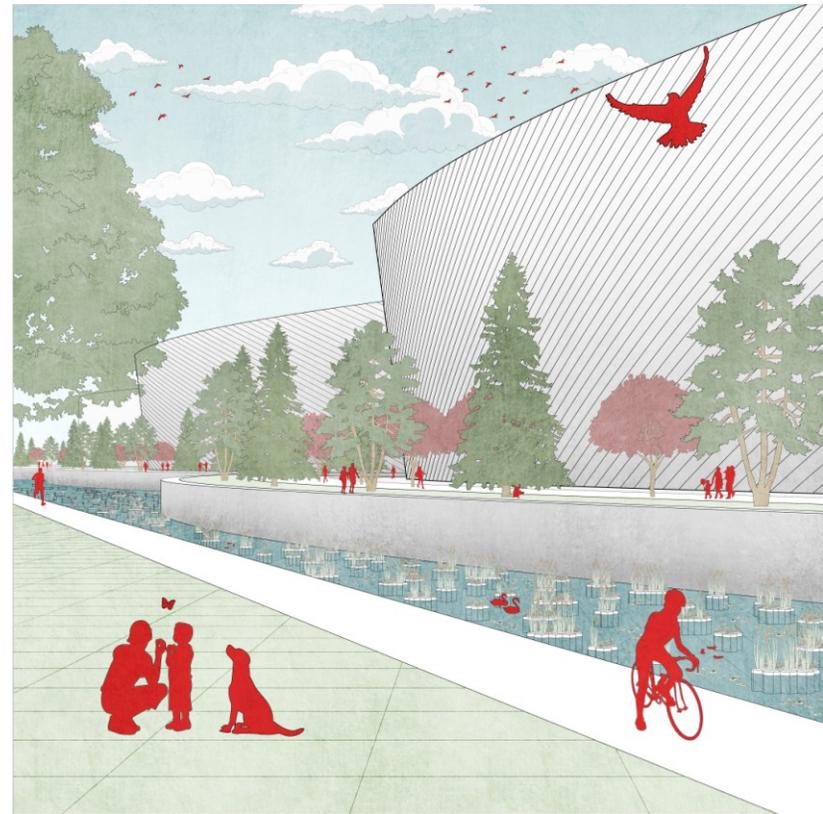


Fig.62: View from Montgomery Park Road.

the proposal

to the U.S. Energy Department's National Renewable Energy Laboratory (NREL), to produce 1 GWh of electricity from photovoltaics, you would require 2.8 acres or 11 331m² of floor area.¹⁶⁰ The 12 available rooftops range in area from 3 200m² to 47 500m², with a total roof area of over 180 000m². With the photovoltaic technology used by the NREL, this much area could provide over 16 GWh of electricity per year. This of course is if the entirety of the roof area was purposed for photovoltaic energy production.

In any case, the site offers an ideal location for the energy redirection from potential off-shore windfarms.

A windfarm placed south of the Pickering site would

¹⁶⁰ Linda Hardesty. "It takes 2.8 Acres of Land to Generate 1GWh of Solar Energy Per Year, Says NREL". Energy Manager Today. August 1, 2013. www.energymanagertoday.com

the proposal

be able to be accommodated here due to the existing electrical lines which exist from the nuclear plant. For the same reason, electrical storage would also work great in this location due to the availability to these electrical lines; one of the two qualities needed for an A-CAES system: electrical infrastructure and adjacency to a large body of water.

the proposal

The Built Form

The theme of water is apparent throughout the site, and even influences the design of the architecture. Although the focus of this project leaned more towards site design, there are several reasons for the design style of the architecture on site.

The shape of each building was molded from the site design, with each building centered around a remediation pool to form individual courtyards. The site design itself draws inspiration from nature; with curves and segmentation inspired by the butterfly --a symbol of transformation and renewal.

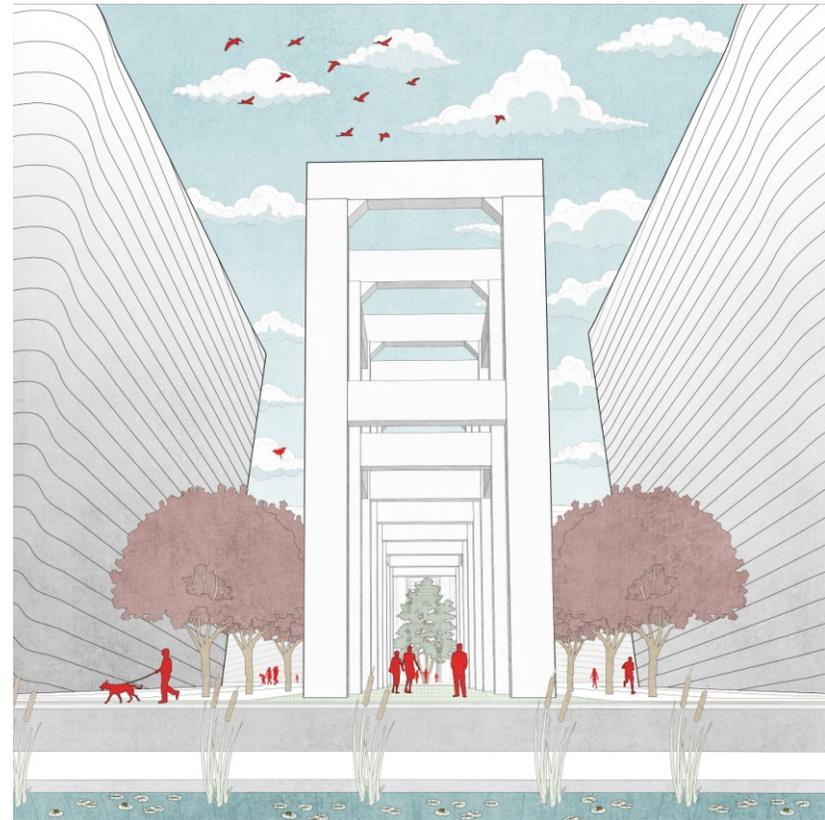


Fig.63: Physical model showing waterfront grading.

the proposal

Along the waterfront, grade has remained the same as the original nuclear plant, however, as you move further into the site towards the reactors, the land has been built up towards the new buildings [Fig.63] to protect from possible flooding and erosion which could occur in the future.

From the site lines, rise these colossal rock formations [Fig.64], constructed from future 3D printed systems which would utilize highly advanced concrete formulas. These concrete mixtures will be self-insulated, made with captured CO2 from our atmosphere, and will even be able to self-repair. These are advancements in concrete construction which exist



Growth or Decay

Fig.64: Support pillars from the vacuum building, repurposed as landscape features.

the proposal

today, and will only continue to improve.

The choice to integrate such large structures was selected for their monumentality. Through the test of time humanity's history has survived with the application of stone in the construction of its civilizations, from the Egyptian Pyramids to the Mayan Temples and beyond, stone has withstood time. But even stone is no match against the force of water.

From Canada's west to east coast you can find renowned examples of water's ability to shape rock. Formations like the Hopewell Rocks in New Brunswick[Fig.65], or the Rocher Percé in Québec [Fig.66] create surreal landscapes and leave us in awe

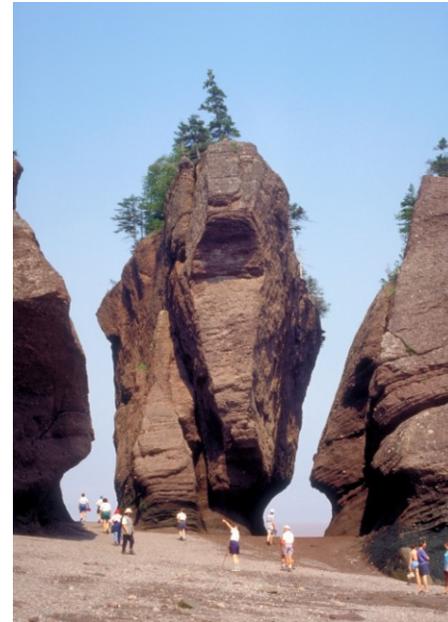


Fig.65: Hopewell Rocks, New Brunswick, Canada.
Source: www.fbramazingplaces.ca

the proposal

of nature.

From the perspectives in figures 59, 62 and 64, you are able to witness the grain of the façade. These slanted lines represent the erosion of rock due to the carving effect of water seen in nature. Placed on an angle, these lines draw the viewer's gaze from earth to sky.

The decision for the scale of these buildings to be quite large was due to the copious amount of space they could provide for current and future program.

The building style was continued from the inland side through to the shoreline to create a unified aesthetic. The reactors, still unsafe for public interaction in their interiors, were embedded within two of the largest



Fig.66: Rocher Percé, Québec, Canada.
Source: www.theculturetrip.com

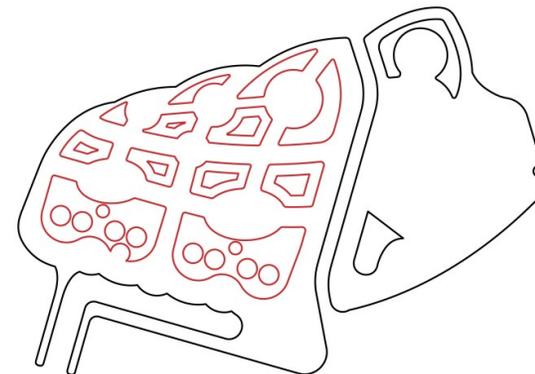


Fig.67: Buildings in red are designed with the same aesthetics.

the proposal

buildings on site. This decision was made due to the added physical protection it would provide, as well as the new chasms acting as a second skin for visitors; a taste of the grandeur of the reactor buildings which await to be opened after their safe storage period. Public interaction would still be encouraged, although it would only occur on the outside of the reactor buildings[See Fig.69].

Due to their safe storage period, the design of any program for the reactor buildings was withheld from this document. This decision was also largely made due to the limited information and access to the reactors. However, one could only imagine the possibilities that these spaces could provide once they

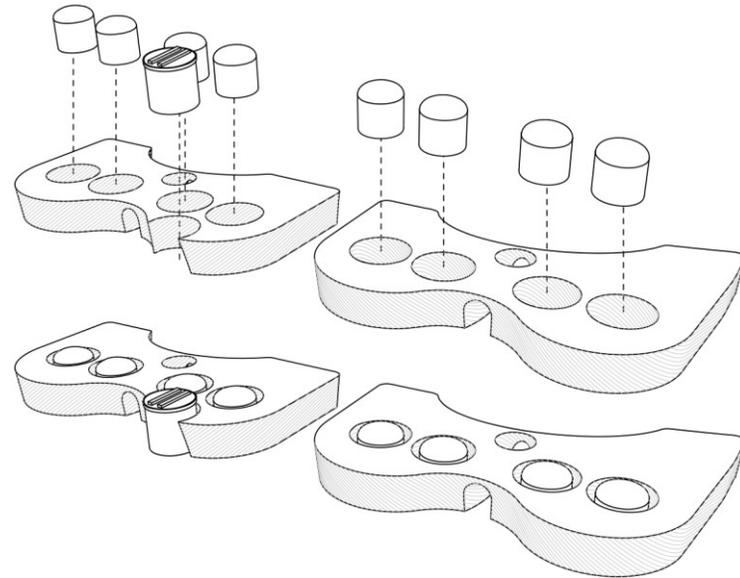


Fig.68: Reactors embedded within their new buildings.

the proposal

are radiation free.

I envision the spectacle of one of these reactors opening to the public after fifty years of safe storage, which not only reveals the history of such a building, but also acts as a reminder of the dangers nuclear energy really poses on humanity.

Together these buildings could offer several million square feet of adaptable floor space; with the added benefit of their increased durability, their lifespan could extend hundreds of years; offering a place of sanctuary; shelter from intensified storms; space for future energy production and water remediation; stable agriculture production for the local populace and above all, a place

the proposal

for community.

Program Test Study: Agriculture

The practice of indoor farming has been implemented in many countries. One of the largest indoor farms is located in Kyoto, Japan and is set to have its first harvest in the fall of this year. The new facility measures in at 3 500m² and is expected to harvest up to 30 000 heads of lettuce per day.¹⁶¹ These facilities utilize energy efficient LED Lighting and require a fraction of the water and added nutrients that conventional farming requires. There is also the added benefit of requiring no pesticides or herbicides due to

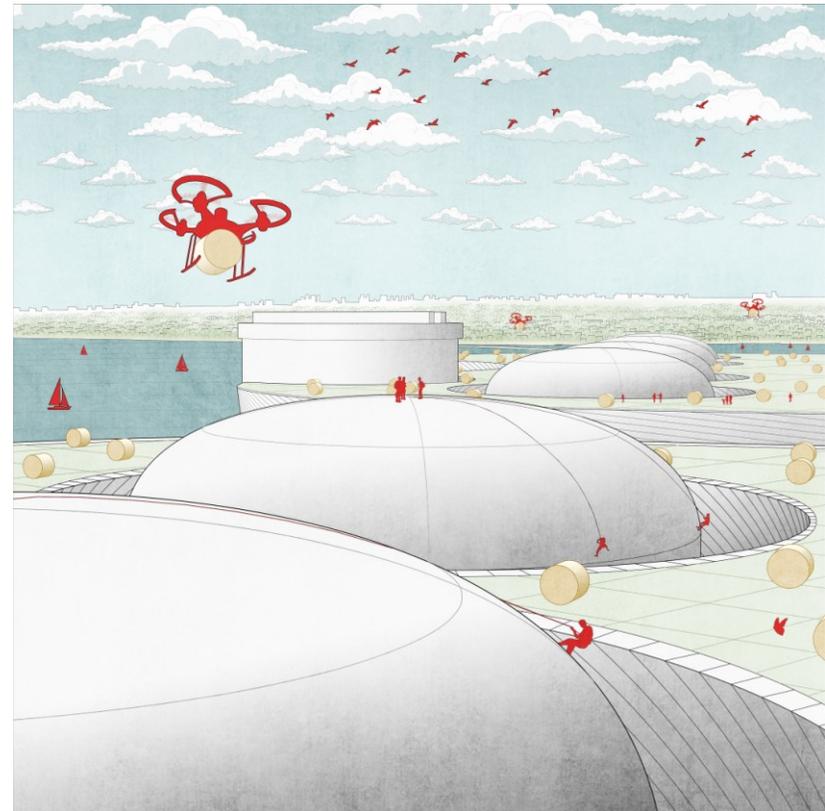


Fig.69: Rooftop view over the reactors towards Toronto.

161 Derek Markham. "Automated indoor vertical farm will produce 30,000 heads of lettuce per day". Treehugger. www.treehugger.com

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the controlled environment indoors.

As a program test I have chosen one of the new buildings on-site to house an indoor farm. Most of the farming on-site would be indoors due to the benefit of a controlled environment and the added productiveness of stacking produce which increases the yields. Other areas such as the many roofs could be designated for agriculture that is not for human consumption, i.e. hay, hemp or grass clippings [As seen in Fig.69].

At the end of this document you will find a section of the chosen building as well as its proper section. The building itself has six stories above ground (not including the roof), and two below, with the lowest

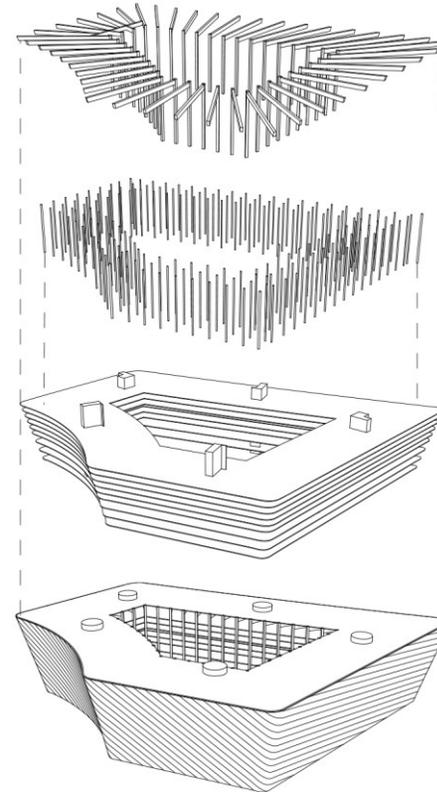


Fig.70: Axonometric of agriculture building showing cores, floors, and structure.

the proposal

floor designated for parking, shipping and receiving.

Out of the nine levels, eight of them could be utilized as space for the indoor farm. In Fig.71 you will notice that the smallest floor plate alone is more than double the size of the Kizugawa farm in Kyoto.

In total there is 88 604m² of useable floor space. If you subtract around 30% of this total for the circulation, the result is 62 000m². Using current indoor farming techniques like that of the Kizugawa farm would result in a yield of over 530 000 heads of lettuce per day. Lettuce, however is not the only possible produce able to be grown indoors, as the possibilities are largely restricted to the general size of the selected produce.



Fig.71: Floor plate sizes for the agriculture building.

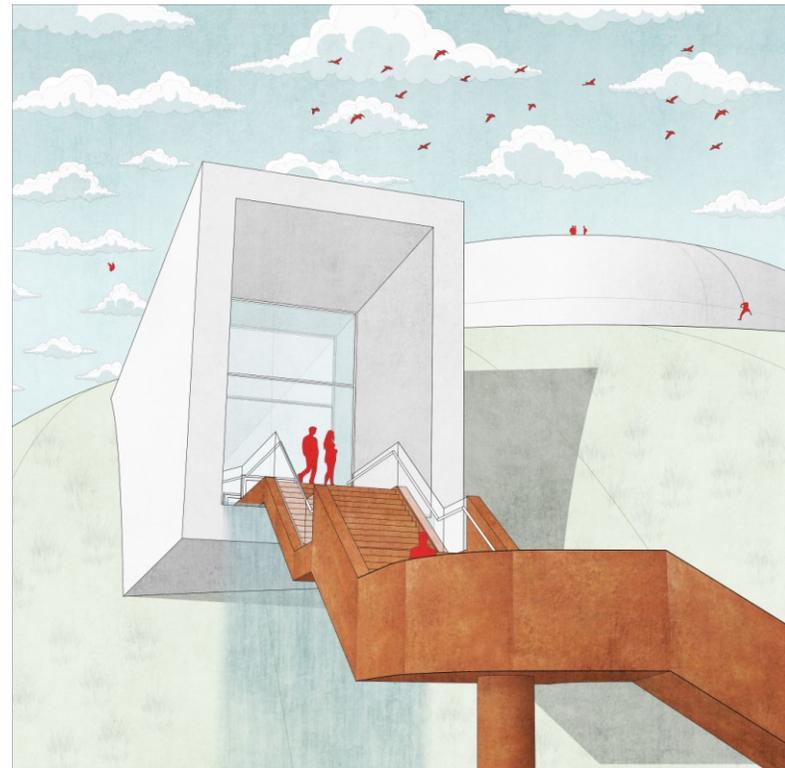
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Following the decommissioning of the site and the development of the new buildings, any possible Tritium contamination would be non-existent due to the fact that at least 25 years would have passed, allowing contaminants to have decayed and become immaterial. This decay period also reinforces the appropriateness for the program selection of agriculture on-site; as the immediate availability to water will reduce cost. There is also the added benefit of the adjacency to the WPCP, which could help to create a closed-loop system and be able to provide fertilizer for added nutrients to the produce grown on-site.

FURTHER EXPLORATION

With the inability to utilize the interior of the reactor buildings themselves, it was important to keep certain infrastructure intact to protect the history of the built form; infrastructure that could be touched and experienced.

The main component of the design is the reuse of the existing vacuum chamber, which was used as the emergency exhaust port from each reactor to the vacuum building. As seen in the Vacuum Level Plans at the end of this document, this extruded rectangular space provides opportunities for exhibition and gallery program.



Growth or Decay

Fig.72: Entrance to East Building.

Entrances have been placed at each end of the vacuum chamber. As seen in Fig.72, the entrances have been accented with grand staircases that as you ascend, direct your view towards the lake, then turn your gaze to face the large concrete entrances. The decision to use rusted steel as the material of choice for the staircases was made due to their affiliation with the theme of decay; as well as to create a powerful yet harmonic contrast with the grays of the concrete.

The entrance is further enhanced with the application of a waterfall; which acts not only as an aesthetical feature but has practical uses as well; refilling and aerating the surrounding remediation pool. As you ascend, the sides of the staircase change from rusted steel to glass, revealing the flowing water and creating the feeling of lightness

before entering the vacuum chamber.

The design of the building was kept quite pure. Surrounding the reactors, the earth is bermed towards the sky, only stopping to reveal the peaks of the reactor buildings which sit dormant, encased by earth and a new outer concrete skin. As seen in the Section Through Reactor drawing at the end of this document, a new space was created between the surrounding earth and existing reactor shell. This space is encapsulated with a rusted steel skin (continuing with the theme of decay), and provides an opportunity for visitors to experience the size of each reactor without having to enter the buildings themselves.

The spaces surrounding each reactor are accessible by

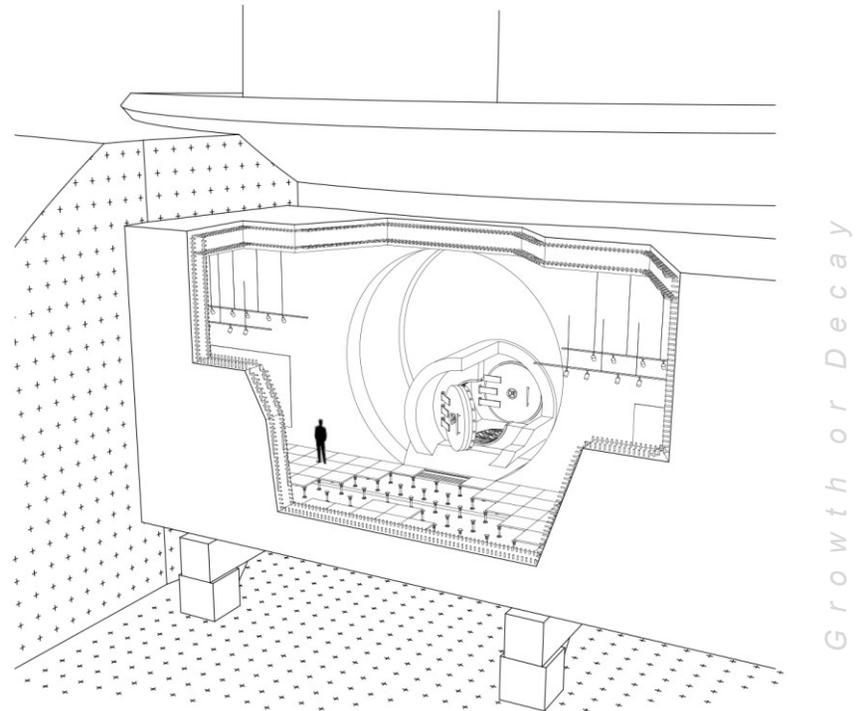


Fig.73: Detail reveal of vacuum chamber & reactor entrance.

newly created entrances at the north ends of each reactor building, as seen in the Ground Level drawings of both west and east buildings. The entrances are accessed by curling pathways which are elevated above a large remediation pool that surrounds the building, Fig.73. While these entrances would in fact have to remain secured for private access only (until the reactors are safely accessible), this outdoor space in the meantime provides opportunities for leisure and self-reflection.

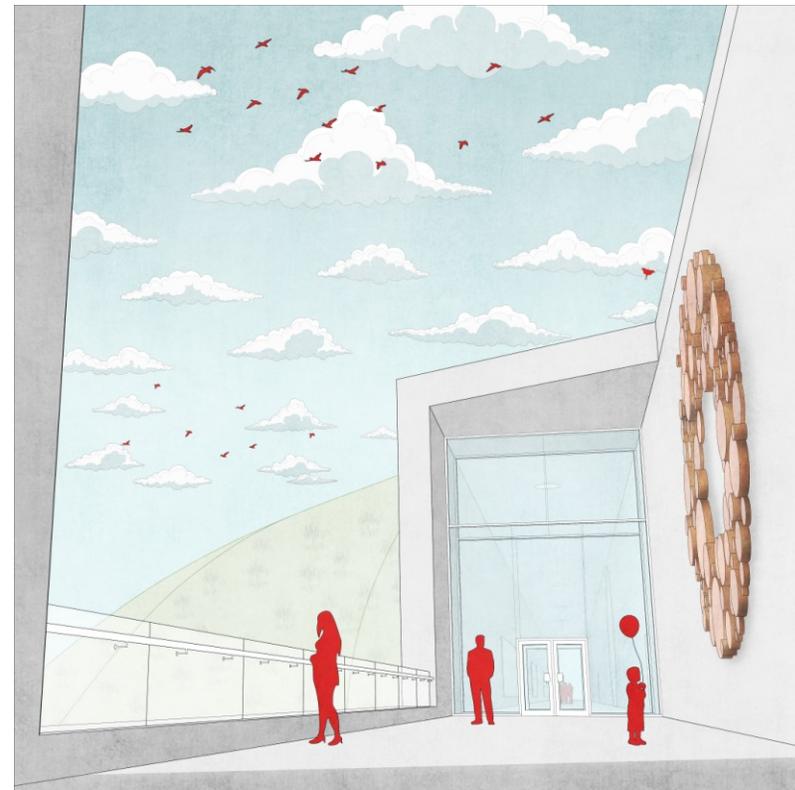
There are also entrances into the reactor via the vacuum chamber. As there already existed an opening from the chamber into each reactor building, new sealed entrances have been placed in these locations, providing further access to each building(See Section Through Reactor or Vacuum Level drawings).



Fig.74: View south towards the East Building.

As you move through the chamber, the space is illuminated both artificially, and naturally during the day with the implementation of new skylights along the long corridor. Dividing the chamber is the outdoor terrace that occupies the center, Fig.74. This space allows for increased natural lighting within the vacuum chamber and provides a raised lookout point to the lake and beyond.

The new reactor buildings were designed to provide a more intimate relationship with the waterfront. The decision to berm around them was made to create the illusion of a more natural environment, however, with the revealing of the tips of the reactors themselves, the theme applied here leads toward the battle of man versus nature, with the reclamation of the built form(reactor buildings)



Growth or Decay

Fig.75: Vacuum Chamber: Outdoor Terrace.

by the berm(nature). This reveal was also meant to metaphorize the nuclear industry as a weapon, imitating missiles in their silos.

The vacuum building itself will be utilized as a pumping station for the adjacent pools, as well as provide other opportunities for the water sector. This is the largest single structure on site and is well reinforced with thick concrete walls and columns (See Fig.52, pg156). The transformation from vacuum system to water system is more so of an engineering task, and so the plan reveals only the existing conditions of the building. New access to the building would have to be created, either via the new accessible entrance to the west building(See Ground Level West Building drawing) or additional entrances around its perimeter.

This approach for the new reactor buildings was aimed towards creating a softer face for the new waterfront. By both concealing and revealing elements of the existing historical infrastructure, a new dialogue has been created which invites visitors to experience and explore.

CONCLUSION

There is great concern in the world today, from political ignorance and climate change, to food and water scarcity, accessibility to energy and even the threat of nuclear war. The important thing to note is that these are almost entirely manmade problems, capable of remediation.

We are at a turning point in our history. We have been using coal, oil and gas for heat and energy, and for good reason; they are incredibly powerful and valuable resources that both provide and store energy at a cheap cost -- unless you take into account their costs towards environmental damage and pollution related health care. However, despite their efficiency and cost, fossil fuels aren't better energy sources than renewables like solar, wind and geothermal. Fossil fuels pollute the environment, cause illness and death, accelerate global warming and damage or destroy ecosystems. They will also eventually run out and are already proving more difficult and expensive to obtain, resulting in dangerous and unconventional methods of extraction such as oilsands, deep-sea drilling and fracking. Even the decision to utilize new nuclear facilities to combat climate change is in fact a lie, as all it is doing is providing expensive electricity rates and stockpiling tonnes of radioactively contaminated materials that will outlive the human species on this planet.

Fortunately, the green movement is growing each day, as clean energy technologies continue to improve daily. Just as society is surprised at the rapid development of computing technologies used in smartphones and other devices, so too will they be amazed at the

developments in renewable energy. Wind and solar are improving and coming down in cost, as are energy storage systems. Even geothermal has the promise of being the future leader in renewable energy production.

Embracing science, innovation and progressive ideas gives us hope for a healthier future. It is unfortunate that so many people, including government leaders in the U.S. and parts of Canada are rejecting brilliant new ideas in favour of outdated and destructive ways of generating energy.

We are well into the 21st century. If humans want to make it to the 22nd, we must change course. Science offers great tools for understanding and innovating. We owe it to ourselves to at least understand how science acquires and integrates knowledge and what that means. We can't just keep digging up and burning non-renewable resources, polluting air, water and land and putting human health and survival at risk. Nor do we have to. We have better options.

Ontario has already pledged support behind its nuclear sector with the refurbishment of the Darlington Nuclear Generating Station, but the Pickering station should not follow suit. This aging giant is surrounded by a growing population and one of the greatest cities in the world in Toronto. The continued reliance on this energy source will only continue to put the population at risk and leave it open to a possible catastrophic event. But with strong leadership and the support of the general public, there is hope for a future here; a safe and sustainable waterfront for current and future generations in the City of Pickering.

WORDS AND TERMS

| | | |
|--------------|-------------|---|
| Anthropocene | <i>noun</i> | The period of time during which human activities have had an environmental impact on the Earth regarded as constituting a distinct geological age. |
| Atom | <i>noun</i> | The smallest particle of an element that can exist either alone or in combination. |
| Aquaculture | <i>noun</i> | The cultivation of aquatic organisms (such as fish or shellfish) especially for food |
| Becquerel | <i>noun</i> | The SI unit of radioactivity, corresponding to one disintegration per second. |
| Beryllium | <i>noun</i> | A steel-gray light strong brittle toxic divalent metallic element used chiefly as a hardening agent in alloys. [Atomic number 4] |
| Cladophora | <i>noun</i> | A genus of branched filamentous septate green algae usually firmly attached and with the branches arising from the upper end of the cells each of which has a reticulate chloroplast and several nuclei |
| Curie | <i>noun</i> | A unit quantity of any radioactive nuclide in which 3.7×10^{10} disintegrations occur per second. |
| Fission | <i>noun</i> | The splitting of an atomic nucleus resulting in the release of large amounts of energy. |
| Half-Life | <i>noun</i> | The time required for half of the atoms of a radioactive substance to become disintegrated. |
| Isotope | <i>noun</i> | Any of two or more species of atoms of a chemical element with the same atomic number and nearly identical chemical behavior but with differing atomic mass or mass number And different physical properties. |
| Microsievert | <i>noun</i> | The SI unit of measurement for the health effects of low level ionizing radiation on the human body. |
| Radium | <i>noun</i> | An intensely radioactive brilliant white metallic element that resembles barium chemically, occurs in combination in minute quantities in minerals (such as pitchblende or carnotite), emits alpha particles and gamma rays to form radon, and is |

| | | |
|---------|-------------|--|
| | | used chiefly in luminous materials and in the treatment of cancer. [Atomic number 88] |
| Uranium | <i>noun</i> | A silvery heavy radioactive polyvalent metallic element that is found especially in uraninite and exists naturally as a Mixture of mostly non-fissionable isotopes. [Atomic number 92] |

ACRONYMS

| | | | |
|-------|---|-------|---|
| AECL | Atomic Energy of Canada Ltd | IPCC | Intergovernmental Panel on Climate Change |
| CANDU | CANadian Deuterium Uranium | ISFSI | Independent Spent Fuel Storage Installation |
| CCNR | Canadian Coalition for Nuclear Responsibility | LLW | Low-Level Waste |
| CEAA | Canadian Environmental Assessment Agency | NEI | Nuclear Energy Institute |
| CELA | Canadian Environmental Law Association | NRC | Nuclear Regulatory Commission |
| CNA | Canadian Nuclear Association | NREL | National Renewable Energy Laboratory |
| CNSC | Canadian Nuclear Safety Commission | NRU | National Research Universal reactor |
| CRL | Chalk River Laboratories | NRX | National Research Experimental Reactor |
| DGR | Deep Geologic Repository | NWMO | Nuclear Waste Management Organization |
| DNA | Durham Nuclear Awareness | OCAA | Ontario Clean Air Alliance |
| EMP | Environmental Monitoring Program | OPG | Ontario Power Generation |
| GDP | Gross Domestic Product | PHWR | Pressurized Heavy Water Reactor |

| | | | |
|------|---|--------|--|
| GHG | Green House Gas | RBMK | Reaktor Bolshoy Moshchnosti Kanalnyy (Light Water Graphite Moderated Reactor) |
| HABs | Harmful Algal Blooms | SNF | Spent Nuclear Fuel |
| HLW | High-Level Waste | UNEP | United Nations Environment Programme |
| IAEA | International Atomic Energy Agency | UNFCCC | United Nations Framework Convention on Climate Change |
| IESO | Independent Electricity System Operator | WNA | World Nuclear Association |
| INES | International Nuclear and Radiological Event Scale | WPCP | Water Pollution Control Plant |

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