PROFOUNDLY MISUNDERSTOOD: NUCLEAR ENERGY IN ONTARIO, 1940s – 1980s

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ABSTRACT

Profoundly Misunderstood: Nuclear Energy in Ontario, 1940s-1980s

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This study examines the intersection between nuclear energy in Ontario, Canada, with popular forces acting upon it between the 1940s and the mid-1980s. It finds that nuclear energy was the target of changing epistemology as society shifted to a post-modern framework in its perception of technology. Technology was irreparably associated with potential encroaching governmental Technocracy. Nuclear was additionally impacted by a societal misunderstanding of the engineering design philosophy, success through failure, as a negative aspect. These factors then combined with the common psychological phenomenon of affective heuristics to produce a society that was fundamentally opposed to nuclear energy on intellectual principles, safety principles, and base psychological principles. It is the finding of this paper that these factors almost assuredly contributed to the cancellations of and shift away from nuclear power in Ontario. This study offers a rebuttal to the overarching popular misconceptions of, and apprehension toward, nuclear energy.

Keywords: Ontario, Canada; nuclear energy; CANDU (Canada Deuterium Uranium); Atomic Energy of Canada Limited; quantitative risk; qualitative risk; post-modern technology; post-modern risk; affective heuristics; technological Progress; success through failure; twentieth-century technology; technocracy.

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All those mentioned above only contributed positives to this thesis. Any negatives and errors are my own.

Ian Ellis

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Abbreviations

Atomic Energy of Canada Limited (AECL)

Boiling-Light-Water CANDU (BLW)

Canada Deuterium Uranium Reactor (CANDU)

CANDU-300MWe (CANDU-3)

CANDU-600MWe (CANDU/CANDU-6)

CANDU-900MWe (CANDU-9)

Canadian Nuclear Association (CNA)

Canadian Nuclear Society (CNS)

Douglas Point Generating Station (DPGS)

Environmental Protection Agency (EPA)

International Commission on Radiological Protection (ICRP)

Nuclear Power Demonstration Reactor (NPD)

National Research Experimental Reactor (NRX)

National Research Universal Reactor (NRU)

Organic-Liquid-Cooled-Reactor Prototype (OCR)

Working Prototype OCR-CANDU (WR-1)

Pressurized-Heavy-Water (PHW)

Small-Modular-Reactor (SMR)

The Canadian Coalition for Nuclear Responsibility (CCNR)

The Canadian Coalition for Nuclear Responsibility – Ontario Chapter (OCNR)

Three Mile Island (TMI)

Introduction

Nuclear energy was the darling invention of the mid-twentieth century. It was hailed as the arbiter of a new age free of international energy reliance and the end of fossil fuels. Canada produced the domestically researched, designed, built, and fueled CANada Deuterium Uranium (CANDU) reactor. CANDU was to usher Canada, but especially Ontario, where CANDU was first produced, into the new age. Canada was envisioned to be a country entirely run on nuclear energy by the exotic and eagerly awaited twenty-first century. However, Canada and Ontario fell extremely short of this vision. CANDU only reached fruition in three provinces by the 1980s and was eventually shunned in Ontario, its province of origin. How did this occur? How did the 'technology of the age' fail to achieve its projected success? CANDU was an unfortunate casualty of the growing wave of post-modernity within twentieth-century North American society. Post-modern notions of technology, Progress, and risk began to dominate the discussion by the 1980s and quickly overpowered the traditional modernist protests.

CANDU will be the foundation of this study as all debate and theoretical discussion engaged with here orbits it, so introductions are necessary. CANDU is a domestically researched and designed nuclear reactor that has been noted for its originality and remarkable defining features. The basis of nuclear physics required to engage within this study is brief, as it is not centred on the nuclear reaction itself. Nuclear reactors function by inducing nuclear fission, the process in which atoms are ripped apart from their nucleus by the impact of high (approximately 95%) and low-speed (approximately 5%) neutrons.[1] Once atoms are detached from their nucleus,

[1] Wei Shen and Benjamin Rouben, *Fundamentals of CANDU Reactor Physics* (New York: American Society of Mechanical Engineers Press, 2021), 16.

they release an exponentially higher amount of energy relative to their minuscule mass. Fission is also referred to as the 'burn rate' of uranium fuel. While fissionable materials do not literally burn, the intended effect is the invocation of traditional fuels such as coal and oil. To sustain a nuclear reaction, these instances of fission must be both self-sustaining, what is called a 'chain reaction,' and they must be stringently controlled, 'moderated,' to ensure the reaction does not reach dangerous levels or, conversely is too weak to produce the desired level of power. On average, for every neutron inducing fission, approximately 2.4 neutrons are produced as fission products.[2] This means that the chain reaction is highly probable under induced fission. Once a chain reaction has been sustained, the reactor is said to have gone 'critical,' meaning it achieved the necessary mixing of the fuel burn rate, moderator control, and safety protocols to function as intended.[3] After criticality is achieved, the chain reaction is then slowly and methodically increased to the desired power output. What made CANDU unique was how the research team at Chalk River, the research lab where CANDU was designed and where Canada's first nuclear reactors went critical in the 1950s, moderated the chain reaction within CANDU.

CANDU is a Pressurized-Heavy-Water Reactor (PHW), meaning the system's moderator is heavy water. Heavy water (D_2O) differs from common light water (H_2O) in that the hydrogen-1 isotope is replaced with deuterium or hydrogen-2 isotope. As deuterium is more massive than hydrogen-1, when combined into a water molecule, it received the moniker of heavy water. Heavy water, due to being a more stable molecule than light water due to deuterium's valence ring being full, is far more likely not to absorb neutrons. This is preferred within a nuclear reactor as the neutrons must be able to travel freely between fuel robs to induce fission

[2] Shen and Rouben, *CANDU Reactor Physics*, 3.
[3] Robert Bothwell, *Nucleus: The History of Atomic Energy of Canada Limited* (Toronto: University of Toronto Press, 1988), 10.

continuously. Heavy water is also essential because it allows the reaction to sustain itself with Uranium-238 (U-238) instead of Uranium-235 (U-235) or Uranium-233 (U-233.) U-238 is the dominant elemental form of uranium, while U-235 is miniscule in prevalence, and U-233 does not exist naturally in appreciable values. U-235 and U-233 are the primary fuels used outside of Canada due to the process of 'enrichment.' Enrichment is the process in which both U-235 and U-233 are isolated within U-238 and artificially increased. The results are appreciably smaller amounts by weight of uranium fuel and the prohibitive expense of building enrichment and processing facilities. Canada did not have these facilities during the 1940s and 1950s and hesitated to rely on American shipments.[4] Additionally, Canada contained an appreciable amount of the world's U-238 within its borders.

This was a deciding factor for the British to form the original 1942 Anglo-Canadian nuclear research project, which led directly to Chalk River's and CANDU's founding.[5] Making avoiding enrichment increasingly enticing. While research into enriched reactors was not to be abandoned for posterities sake, by 1950, W. B. Lewis, director of Chalk River between 1946 and 1952 before becoming vice-president of the newly formed Atomic Energy of Canada Limited (AECL) in 1952, had tabled a full proposal for a natural uranium-fed and heavy water-moderated power reactor.[6] This was the official and immovable foundation for the proceeding iterations and prototypes of CANDU reactors. The name CANDU would be officially adopted in 1958, but the throughline directly connected it back to Lewis' 1950 proposal.[7] CANDU refers to both the base design of heavy water-moderated and natural uranium-fed Canadian reactors while also being the

[4] Shen and Rouben, *CANDU Reactor Physics*, 18.; Bothwell, *Nucleus*, 56-57; Gord L. Brooks, *A Short History of the CANDU Nuclear Power System* (Chalk River: Atomic Energy of Canada Limited), 9.
[5] Bothwell, *Nucleus*, 12-14.
[6] Bothwell, *Nucleus*, 186.
[7] Bothwell, *Nucleus*, 256.

colloquial term for the CANDU-Pressurised-Heavy-Water Reactor or CANDU-6. The CANDU-6 became the flagship reactor of AECL and would be found in all major Ontario nuclear sites, such as Douglas Point, Pickering, Bruce, and Darlington. While some prototypes did radically alter the design of CANDU, such as the Organic-Liquid-Cooled (OCR) and Boiling-Light-Water (BLW) Reactors, CANDU-6 was the reactor in reference when any mention of CANDU or Canadian nuclear was mentioned unless otherwise directly specified. As such, unless otherwise specified when CANDU is mentioned within this paper, it is in reference to the CANDU-6 program. The BLW and OCR Reactors will be discussed within this paper, but they are within their own section within Chapter Two to avoid confusing terms.

These factors were all quite standard within the realm of nuclear energy research and technology. Meanwhile, outside of the academic and applied physics departments, there was specific resistance to certain parts of the growing nuclear sector. For example, Canadian-American anti-nuclear activist and spokesperson Dr. Rosalie Bertell was vehemently against nuclear energy on the basis of supposed radiation dangers. Bertell published the *Handbook for Estimating Health Effects from Exposure to Ionising Radiation* (1984; 2nd ed., 1986). The *Handbook* would be the synthesis of Bertell's career and offered the foundation for Bertell's 1985 *No Immediate Danger? Prognosis for a Radioactive Earth.* Bertell's *Handbook* attempted to maintain a veneer of scientific objectivity, while *No Immediate Danger* shed it immediately in favour of a polemic against nuclear energy. Both works are critiqued and found to be unobjective and ideologically motivated in Chapter Three. After Bertell, the most important anti-nuclear activist was Dr. Amory Lovins. Lovins, a physicist and prominent member of various American oil lobby groups, was diametrically opposed to nuclear energy based on fears of inadequate reactor safety in addition to his mistrust of the nuclear industry. Lovins wrote his 1979 polemic

Soft Energy Paths: Toward a Durable Peace under the cloak of neutral scientific objectivity, but his arguments and conclusions lack evidence in their favour, ignore the evidence against his arguments, and despite his saying so, the entire book is opposed to nuclear energy on principle. Lovins opens *Soft Energy Paths* with the "grave" acknowledgement that the energy sector has devolved into a place of "centrism, vulnerability, technocracy, repression, alienation…"[8] Lovins has openly declared his opposition to the classic energy sector and cites E. F. Schumacher's 1973 *Small is Beautiful: A Study of Economics as if People Mattered* as influential to his arriving at this conclusion.[9] Alongside a full analysis of Lovins in Chapter Three, Schumacher's chapter on nuclear energy, *Nuclear Energy – Salvation or Damnation?* will be analysed alongside Lovins.

Both Bertell and Lovins were opposed to nuclear energy from primarily scientific or safety points of view. Meanwhile, philosophers, most notably in the Canadian context, George P. Grant, were opposed to the proliferation of technology based on sociocultural fears of a looming Pan-American technocracy. Grant elucidates a theory scattered across his writings that the homogenization of Canadian culture with American culture would create a Pan-America empire. This empire, according to Grant, would use technology as their primary tool to achieve these ends. Grant's writings, developed across the 1950s to 1980s, form the basis of Canadian intellectual and ideological resistance to nuclear proliferation in Canada. Due to a series of factors that will be discussed throughout this introduction and the entirety of Chapter One, technology has ceased to be an inert item. Literal technology had been superseded by metaphysical "Technology" and was given agency it did not possess prior. This conversation had been evolving over the nineteenth and twentieth centuries, but it seems to not have directly

[8] Amory B. Lovins, *Soft Energy Paths: Towards a Durable Peace* (New York: Harper Colophon Books, 1979), 6.
[9] Lovins, *Soft Energy Paths*, 11-12.

impacted Canadian nuclear energy until the debates of the 1960s-1980s emerged. As such, this study focuses on the post-war era of Canada, during which intellectual resistance to Technology exponentially increased in Canada, specifically Ontario. These issues would all come to a head in the debate over Ontario's nuclear energy sector during the 1970s and 1980s, well into the CANDU life cycle. These issues emerged due to the increasing prevalence of post-modern thinking regarding the essence of technology and the contrasting views and philosophies of safety and risk between modernist scientists and post-modernist risk analysts.

The explicit goal of CANDU was simple: to fill the projected gap in domestic energy production with a clean, reliable, and domestically produced technology.[10] This came years after 1949 when W. B. Lewis acknowledged that Chalk River would need to produce CANDU out of economic reality to fund their pure physics research.[11] This reality continued to be openly acknowledged until 1964.[12] Meanwhile, influential post-modern thinkers such as Grant were building a conception of society in which Technology was imposed upon the populace to control and assimilate them. Grant's ideas opposed those of his theory of Technology peers. Harold A. Innis' balanced approach and Marshal McLuhan's idolatry were opposed by Grant's enthusiastic support for this technological dependence thesis. The culture that emerged around the theory of Technology within Canada during the 1960s-1980s, in particular, is of immense consequence to this study. Without the philosophical basis of Grant's dependency thesis, the anti-nuclear establishment would almost assuredly not have produced as organized an effort to oppose nuclear technology in Ontario. This post-war philosophical base is elemental to the discussion of

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[10] *CA2ON-Z1-756002. Royal Commission on Electric Power Planning: Interim Report on Nuclear Power in Ontario: A Race Against Time*. Presented to Minister Rene Brunelle, 12 September 1978. XI.
[11] Bothwell, *Nucleus*, 173.
[12] A. J. Mooradian, *AECL-1985: The Definition and Achievement of Development Targets for the Canadian Power Reactor Program*, (Chalk River: Atomic Energy of Canada Limited, 1964), 1.

nuclear energy in Canada during the latter half of the century and, as such, will form the base of this paper. With particular emphasis on staple theories and essential distinctions, Chapter One offers the foundation on which the remainder of the paper's arguments appear. Chapter One, once the necessary base theory has been established, followed by Chapter Two, details the tangible issues of nuclear energy. Namely, reactor safety and examples that disprove post-modern assertions of Technology.

CANDU safety was an evolving conversation that spiked in the late 1950s before going mostly dormant until the 1970s, when it spiked to all-time highs and remained so. Safety was called into question after the 1952 National Research Experimental (NRX, a test reactor built prior to the first CANDU) accident in which a concerted clean-up effort was mounted. While no injuries or dire consequences emerged, as shall be outlined fully in Chapter Three, the negative publicity haunted AECL for years. This negativity was reinvigorated in 1958 after NRX's successor, the National Research Universal (NRU), experienced a small accident that required the reactor to be shut down for three months. Both reactors' remarkable failures were perhaps one of the most fortunate episodes in CANDU's design philosophy. As a result of the accidents, AECL overhauled and radically changed its safety design philosophy. This change was headed by G. C. Laurence, the eventual president of the Atomic Energy Control Board from 1961-1970, Canada's nuclear safety regulation agency, who by 1972 had successfully implemented a comprehensive reactor safety philosophy for all AECL reactors and presented them in full during an industry meeting.[13] With these two events as dark marks on its record, AECL continued forward with nuclear reactors, officially dubbing the design CANDU in 1958 while building the

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[13] G. C. Laurence, *CA2ONRC75E6330: Nuclear Power Station Safety in Canada*, Presented at the Meeting of the Niagara-Finger Lakes Section of A.N.S., (January 1972), 1-11.

National Power Demonstration (NPD) reactor. CANDU would then go on to have zero major accidents from 1958 to 1989. While CANDU continued beyond the twentieth century to be free of major accidents, that is beyond the scope of this study and is not included. What is relevant is that both the NRX and NRU accidents, despite their laborious decontamination and rebuilding processes, produced zero accountable fatalities immediately or over the succeeding thirty years.[14] This information will be relevant in dispelling anti-nuclear disinformation that emerged regarding the accidents that targeted CANDU in the 1970s and early 1980s. This information forms an arm of the argument of Chapter Three.

In fact, the main examples used to argue that CANDU was unsafe were from radically different reactor designs. March 1979 saw the notorious Three Mile Island (TMI) Accident in which one of the reactor cores experienced a meltdown. While an instructional event for CANDU designers and operators, it was not directly applicable to CANDU safety because the TMI reactor was a Pressurized Water Reactor that utilized a light water moderator and enriched fuel. The second accident was the Chornobyl disaster of 1986. Chornobyl whipped fear of nuclear energy into a frenzy, which turned its eyes onto CANDU. AECL took numerous teachings from Chornobyl, but given the vastly different technical systems (Chornobyl was an RBMK reactor, never produced or sold outside the former Soviet Union), the teachings could only go so far. Meaning the various reactor designs differed radically in their operation and safety procedures. CANDU utilized a unique triplicated safety system. Within this system, every piece of equipment would need to fail three times to destabilize safety integrity, and under AECL

[14] M. M. Werner and D. K. Meyers, *AECL-9344: Mortality Among Long-Term Chalk River Employees* (Chalk River: Atomic Energy of Canada Limited, 1986), 2-4.; M. M. Werner, D. K. Meyers, and D. P. Morrison, *AECL-7901: Follow-Up of AECL Employees Involved in the Decontamination of NRU in 1958* (Chalk River: Atomic Energy of Canada Limited: 1982), 6-9.; M. M. Werner, D. K. Meyers, and D. P. Morrison, *AECL-7760: Follow-Up of CRNL Employees Involved in the NRX Reactor Clean-Up*, (Chalk River, Atomic Energy of Canada Limited, 1982), 6-9.

regulations, the chances of a single failure must be kept below a maximum of 0.003% per year.[15] This system was then additionally bolstered by separating equipment into three categories (process equipment, protective devices, and containment provisions) that encompassed all aspects of the reactor and each section was isolated from the others.[16] This means that a failure in one category was incapable of expanding beyond its own category and producing a chain reaction of failures. This dual acceptance of risk as inevitable while simultaneously rendering it as unlikely as possible is the core tenet of the realist approach to risk and safety, which forms the core opposition to post-modern theories of risk and the main argument in Chapters Two and Three.

CANDU design was an iterative process that required numerous stages to achieve progressively more complex goals. For example, NRU, in the late 1950s, introduced online refuelling, which was a world first for nuclear reactors.[17] NRUs successor, NPD, would expand upon the online refuelling designs but experience numerous problems with the refuelling process, such as fuelling machines not achieving a perfect seal during fuel transfer, resulting in substantial heavy water leaks or the inability to refuel safely.[18] While some leaks were there by design to keep seals lubricated and the system cooled, these leaks were beyond the normal range.[19] The seal rings connecting the fuelling machines to the fuel channels would, on average, fail after 200 working hours.[20] These errors were steadily being rectified. However, with the construction of NPD's successor, the Douglas Point Generating Station (DPGS), the first full-

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[15] G. C. Laurence *et al.*, *Reactor Safety Practice and Experience in Canada*, Presented at the Third U.N Conference for the Peaceful Uses of Atomic Energy. August-September 1964. Vol. 13. 317.
[16] Laurence, *et al.*, *Reactor Safety Practice*, 317.
[17] Gord. L. Brooks. *A Short History of CANDU*. 8.
[18] L. W. Woodhead and W. M. Brown. *Performance and Problems of NPD*, Presented at the 1964 U.N Conference for the Peaceful Uses of Atomic Energy, 314.
[19] Woodhead and Brown. *Performance and Problems of NPD*, 315.
[20] Woodhead and Brown. *Performance and Problems of NPD*, 315.

scale consumer power CANDU, critical in 1966, these issues would emerge once again. DPGS was built in Kincardine, Bruce County, on the shores of Lake Huron and was equipped to produce 200 MWe of power compared to NPD's 20 MWe.[21] NPD, DPGS, and all subsequent CANDU reactors were built at the impetus of AECL and approved by both the respective provincial and federal governments. DPGS would experience failures due to faulty fuelling machines, operators' inexperience with online refuelling (still novel at this time), and mechanical errors such as fuelling machines locking onto the reactor.[22] These issues are essential to the discussion within this paper due to its invocation of the engineering mantra of 'success through failure.' Success through failure was popularized by engineering and the history of science professor Henry Petroski in his guiding work *To Engineer is Human: The Role of Failure in Successful Design* (1985), which gave success through failure its popularity outside of the sciences. The concept would prove so popular Petroski published a monograph exclusively on its role in design and technological achievement titled *Success Through Failure: The Paradox of Design* (2006).

The core tenet of success through failure is that the emergence of a failure data point is far more conducive to sound scientific advancement than a successful data point. This is due to the dual nature of failure. Being if System A fails, the engineer knows with certainty that A must be replaced with B and so on, until the system succeeds. Thus, the engineer knows that both A is faulty, and whatever replaces A is effective because it removes the issue. Meanwhile, if System A had immediately worked, the engineer would, in actuality, have learned nothing. Without the data points of specific failures, one cannot know if the system in place is operating as efficiently

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[21] Bothwell, *Nucleus*, 228.; Mooradian, *AECL-1985*, 2.
[22] J. H. Armstrong, *72-CAN-301 Operating Experience at Douglas Point GS* (Chalk River: Atomic Energy of Canada Limited, 1972), 2.

as possible with no superfluous parts. Also, without failure, it cannot be known if A is the best solution for the problem or one that just happens to work. Using an example from the above section, NPD fuel channel seals failed after 200 working hours in 1964, exceptionally lower than anticipated or desired. Upon inspection, it was found gas was being improperly vented into the seals, which compromised their integrity.[23]

With this failure data in hand, the design surrounding the seals was changed to accommodate increased degassing, venting, and changes to seal design, the seal life cycle was increased to a range of 9,000-27,000 working hours by 1971.[24] These changes were then applied to all CANDU reactors, moving forward with additional refinements as needed. This example, as minuscule as a seal ring, expands to encompass CANDU as a whole. CANDUs were built in an iterative process that allowed for ample time to learn from and rectify mistakes in past designs. This process forms the basis and main subject matter of Chapter Two. Chapter Two converses with the theory of Chapter One and concludes that the implementation of success through failure within CANDU does not support the conclusions of the post-modern theories applied to it. This results in Chapter Three, which combines the metaphysical theory of Chapter One and the practical realities of Chapter Two and applies them to the realities of Ontario during the 1940s-1980s. These chapters detail the main issues surrounding nuclear energy during the 1940s-1980s and offer one possible explanation of how they contributed to the overall movement of events. As Ontario, at the time of writing, moves to revive the nuclear energy industry, these issues may become extremely relevant once again, and it is essential that past events are known and offer an opportunity for learning.

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[23] Woodhead *et al.*, *AECL-3972: Commissioning and Operating Experience with Nuclear-Electric Stations* (Chalk River, Atomic Energy of Canada Limited, 1971) 4.
[24] Woodhead *et al.*, *AECL-3972*, 4.

The three main issues to understand about a potential post-modern society are that it fundamentally misunderstands science, technology, and risk. Where an accurate understanding of science was found in modern society, such as the conception and production of technology, it would later be warped in post-modern society. Yet, technology, even after finally being realized, itself is misunderstood in the post-modern notions of Progress and the metaphysical concept of Technology. Post-modern Technology is perceived as the first step toward centralized technocracy in Western government. This post-modern conception is fundamentally misguided. Secondly, this post-modern framework does not include the fundamental notion of failure in science and technology. The greater success in design is a failure, as it eliminates unknowns. This is Petroski's notion of 'success through failure.' Finally, risk management has mutated into the fear of any risk being present, rendering all risks unacceptable. This intolerance is fundamentally hostile to the practice of success through failure, as the adherence to a zero-tolerance policy for risk does not allow for any iterations and upgrades via failure data. CANDU is a prime example of why these post-modern notions are misguided and false.

First, CANDU was targeted by growing fears of centralized technocracy in Canada, which proved false. There cannot be a 'law' of history when examples directly disprove it. Second, CANDU continuously failed on its way to becoming one of the safest, most efficient and reliable nuclear energy technologies in the world. Third, nuclear energy internationally and CANDU nationally have been the subject of decades of debate between various post-modern schools of risk against the scientific quantitative approach. As a case study in risk, CANDU displays every marker present in the theory of risk, attached symbolic meaning beyond the literal technology, technological ignorance, psychological biases and heuristics in the public, and the imbalanced nature of the debate between the public and crown corporations/private industry.

Thus, CANDU, particularly between its conception in the 1940s and the 1980s, is a prime example of conflicting theories of technology, the iterative engineering design process, and the risk debate. This study concludes that these factors combined to form a uniquely united and all-encompassing resistance to nuclear energy in Ontario and perhaps can be credited with contributing to the near forty-year moratorium on new nuclear builds in Ontario.

The theory of the history of science and technology lies at a unique intersectionality of various disciplines. The dominant conflict in the theory is the disagreements between modernists and post-modernists about the direction and purpose of the field. Post-modernists subscribe to the view that science and technology are the main drivers of literal progress (e.g., economic growth, lower mortality rates, greater comforts, etc.) but also metaphysical Progress. The notion of society moving forward on a determined trajectory toward a more stable, just, and prosperous version of itself. While science is necessary to produce literal technology, the post-modernists have placed their faith in the higher notion of Technology. Metaphysical Technology is the blanket term for literal technology or inventions that push society along the path of Progress. This new Technology does not need to be a literal technology (i.e., something manufactured or capitally produced) but must be attached to a larger abstract notion in society. Leo Marx, a staunch modernist, derisively suggests the new Technologies of persuasion and love-making.[25] Metaphysical Technology is a poor descriptor and term for two main reasons. First, the umbrella term 'technology' is vast and unwieldy. Within Wittgenstein's category theory, objects within a group must share characteristics with each other to belong to the same group.[26] Where do the boundaries lie for Technology? If the steam engine, smartphone, bone needle, and propaganda

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[25] Leo Marx, "On Heidegger's Conception of 'Technology' and Its Historical Validity," *The Massachusetts Review* no.4 (1984): 638.
[26] Marx, "On Heidegger's Conception," 639.

are all Technologies, where is the uniting quality? Is the uniting quality that they are all tools used by humans to reach their ends? Then, literally, everything humans ever interact with has become Technology, rendering the term meaningless.

Second, the salient problem is that Technologies cannot act with unique agency. Technology cannot be said to drive history any more than any singular tool. It would be tenuous to argue that Western Europeans successfully colonized vast swaths of the world solely because they had muskets. Movements of history cannot be reduced down to a singular object or group of objects. This strips agency of the humans wielding them and feeds back into the concept of Reification. Thus, the post-modernist history of science and technology literature expounds upon the merits of literal and metaphysical technologies that are perceived to have contributed to Progress. Modernists oppose these notions of Technology and Progress. Modernists contend that literal technology is nothing more than tools humans use for whatever ends they deem fit, and there is no narrative of Progress attached to technology. Post-modern theories of technology have not been met with the skepticism of similar ideas in other areas of history. It must be noted that in broad schools of history, the 'historical law' and determinism arguments have been challenged for over a century. Post-modernists believe that Progress is the direct product of metaphysical Technological innovation and expansion. This Progress cannot be interrupted and will continue *ad infinitum*. This is potentially unwise to defend from a historical point of view.

History cannot be governed by laws such as those governing physics. Within physics, for example, Newtonian gravity was proven wrong in the twentieth century and remade into Einstein's theory of special and general relativity. Newton's theory of gravity was a worldwide gospel for two centuries before being struck down. Thus, the history of physics had not been working towards Progress during those centuries but laboured under a false paradigm. Once this paradigm shift occurred, mass advancements in physics and adjoining subjects were possible because the theory of relativity (the tool) was improved. The theory of relativity is a concept, an abstract notion and a theory. It cannot move towards Progress in any way because it has no agency of its own. It moves in whatever direction humans wield it. Humans wielding the tool are not working to predetermined Progress because there is no being or law governing the end goal of Progress. Technology is no more than a tool labouring under the direction of its flawed users. Leo Marx warns of ascribing human characteristics and agency to technology, giving it a "Phantom-objectivity," invoking the concept of Reification.[27] This Reification of the broad system of technology obscures the human factor behind every choice made in producing and using said technology.[28] Human behaviour and free will are not governed by any beings or laws outside the singular human's mind. Conceivably, if every human were familiar with a piece of technology, then every human would be capable of using it in a different way. Gone are the simplistic days of determinism in which a god or overarching plan was seen to guide human endeavour and decisions. Post-modern ideas of Progress hold onto the comfortable notion that everything is predetermined and the only way forward is upwards. This cannot be vindicated throughout all of history.

Nuclear energy has been entrenched in the middle of this conflict since its inception. Post-modernists argue that nuclear energy is a watershed moment for Progress as it confirms that humans can master the very atoms of the universe. This literature has a special emphasis on the beginnings of nuclear power, such as the Montreal Laboratory (the founding agency of Canada nuclear energy, direct predecessor to Chalk River) and the Manhattan Project in America. This

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[27] Leo Marx, "Technology: The Emergence of a Hazardous Concept," *Technology and Culture* 51, no. 3 (2010): 576.
[28] Marx, "Hazardous," 576.

special emphasis emerges from the idea that new technology is produced (invention) and is immediately followed by an intense phase of refining (innovation), and these two phases produce exponential Progress.[29] Once this period of Progress is over, society moves on to looking for another invention to spur Progress forward. The original technology is then left behind in the literature. Additionally, technologies that were essential during the period under study but eventually fell out of use are rarely mentioned in the literature. David Edgerton argues that because these technologies have fallen away over time, neither came into widespread use nor were "self-evidently important," which is why the literature scorned them.[30] The historical literature of CANDU displays this exact pattern. The Montreal Laboratory and the early years of Chalk River Laboratories, where the first Canadian nuclear reactors went critical, have been covered *ad nauseam*. In contrast, the succeeding years are seldom touched. Robert Bothwell's *Nucleus* is the only significant historical work to extend appreciably beyond this period. *Nucleus* reserves half of its page count for this period, 1942-1955, and the remaining half for 1956-1988. This stems from the valuation of innovation and novelty as higher than any other factor about the technology.

The beginnings of Canadian nuclear energy have been covered extensively, while the subsequent decades are left to languish. Resulting in post-modernist literature having an uncritical, idolatry, ideological view of early nuclear energy development while willfully ignoring the remainder of its history. Edgerton laments this practice as "[invoking] the spectre of a darkly ignorant past, and enlightenment in 'recent years,'" with the process repeating itself

[29] David Edgerton, "Innovation, Technology, or History: What Is The Historiography of Technology About?," *Technology and Culture* 51, no. 3 (2010): 686-687.
[30] Edgerton, "Innovation," 687.

infinitely.[31] As the notion of Progress is ever advancing, what was once a novel, enlightening technology is now mundane, and the post-modernists must search for a new Technology to Reify. In the eyes of post-modernists, the markers of what is worthy of study are forever moving forward and upward on the curve of Progress. Modernists call for an unentangling of literal technology, such as nuclear energy, from Technology so that it may be critiqued and analysed from a historical perspective over its entire life cycle rather than the frantic flurry of research at the beginning and dearth that follows.

Post-modern notions of technology are the prevailing theory within the literature. The modernist idea of inherently neutral technology has largely been left behind in public conceptions. As post-modern conceptions of Technology tie it so closely to Progress, a generalized fear of centralization and technocracy emerges in the public. Eminent writers such as George Grant over the 1950s to 1980s stoked these flames by contending that Technology was the first step to a new North American Empire under a centralized state overseen by technocrats so far removed from the lay population that they seemed to stop speaking the same language. Unfortunately, this fear of technocracy was tied to nuclear energy quite early in its life cycle. By the 1970s, nuclear energy was seen as *the* technological symbol of a centralized technocratic government in Canada. How this symbolic attachment came into being will be built throughout the main Chapters of this work. Canadian nuclear energy had no intentions of being a symbol or stooge of Ottawa. In 1949-1950, W. B. Lewis, then Director of Chalk River, intended to produce nuclear power as a means to an end to ensure Chalk River would continue to be funded in their pure physics research.[32] Lewis and other members of Chalk River management, such as eventual

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[31] Edgerton, "Innovation," 681.
[32] Bothwell, *Nucleus*, 173.

Vice President of Operation A. J. Mooradian, saw producing nuclear power as an economic necessity, not as the ultimate goal of their program in 1964.[33] Yet, due to popular belief that technology cannot be neutral, it was chained to grievances toward the federal government for its entire life cycle. This symbolic stigma had numerous consequences for the conversation of nuclear energy risk in Canada and, ultimately, its future in Canada.

Some unfortunate confusion of terms is necessary. The post-modernist theory of Technology is detailed above. Another group of theorists and theories pertinent to this study are also called post-modernists. Specifically, post-modernist theories of risk emerged in the mid to late-twentieth century. This group can be further broken down into the 'risk-society thesis,' the 'governmentality thesis,' and the 'sociological thesis.' These are all sub-fields within the larger field of the post-modernist interpretation of risk and risk theory. Their most vocal detractors are the 'modernists/realists.' While the various post-modernists base their theories on qualitative perceptions, risks as feelings, the realists base their interpretation on quantitative models and impartiality. Realism has been the prevailing risk assessment system of the sciences and governments since the Industrial Revolution. Realism contends that the risk of any system can be calculated and prepared for to a reasonable extent. Realism accepts that there will always be risk and that there will always be the chance of disaster or great benefit as a fact of life. Great benefits derived from risks can occur in the form of failure data or surprising success. Both are equally important in the discussion of risks. Failure data is crucial to the design and iteration process in every technology. As failures occur and are rectified, the system is made safer and more reliable while simultaneously eliminating faulty design from all future iterations. If this process does not occur, a technology, such as nuclear reactors, would be put into service with an

[33] Mooradian, *AECL-1985*, 1.

insurmountable number of risks and deficiencies. This is the same logic as success through failure and was the risk framework utilized by CANDU and AECL during the years in question between 1940 and the 1980s.

Under post-modern notions of risk, once these deficiencies manifested themselves, the technology would be abandoned in the name of zero risk. Or new technologies would cease to materialize because it is an impossibility to produce a zero-risk technology. Design risks also provide the potential for great unexpected benefits. For example, the CANDU design team risked the entire design by radically changing from the internationally standard pressure vessel design to the emerging pressure tube design in 1957. This had the potential to undo the fifteen years of accumulated failure data and reactor test data. However, the pressure tube design exceeded all expectations and is now one of the defining features of CANDU. Under the post-modern notion of eliminating all risks, such a leap as radically changing the entire reactor design over a decade into production would have been inconceivable, and CANDU would not be the technology it is today. This benefit could not have occurred without the initial risk. While post-modern conceptions of risk call for the total eradication of risk from technology and life. These opposing schools meet over nuclear, with the realists contending nuclear is safe enough and the post-modernists retorting ‘safe enough’ is still too risky and nuclear reactor operations must cease.

This paper was researched by gathering primary sources from official AECL publications, papers/typed speeches presented at national/international conferences pertaining to CANDU, government reports and publications, newspapers, private interest group/industry publications, volunteer group publications, and secondary source literature. The purpose of this paper is not to examine the international or fully national scope of the CANDU program. The focus of this work has been centred on Ontario for manageability and the provinces’ ability to illustrate the relevant examples to the discussion. Ontario is the birth province of CANDU, and it is also the province in which it fell from grace the hardest in the 1980s. As such, this paper will remain focused on Ontario throughout. Historiography began contemporaneously with the development of Canadian nuclear energy in the early-mid 1940s. For the purpose and scope of this project, it is included until the end of the 1980s. The 1980s was chosen as the termination point because the last CANDU constructions began in this decade. Darlington Generating Station was approved in 1977 and met continuous delays until construction began in 1981, which would continue throughout the decade.[34] Due to the culmination of the numerous significant factors discussed here, Darlington was the last major nuclear project completed in Canada.

The historiography of CANDU is quite disconnected, with most accounts isolated into respective sub-fields. Few works deal with the technology on the whole, reference one another, or try to place themselves within the larger context of twentieth-century Canada. For example, *Canada Enters the Nuclear Age* (1997), edited by D. G. Hurst, is the most comprehensive technical history monograph on CANDU in existence, yet it can run for multiple chapters without mentioning outside factors influencing CANDU development. The resulting image is that CANDU was largely created in a vacuum of pure scientific interest unaffected by the outside world. Hurst is the purest form of a technological modernist who believes that technology speaks for itself. Most literature in the field pertains to specific and minute details of the field. Such as D. M. LeBourdais' *Canada and the Atomic Revolution* (1959), which details the history of Canadian uranium mining, and Gordon Sim's *The Anti-Nuclear Game* (1990), which focuses entirely on misinformation spread about nuclear energy in Canada. Of the specialized works, it is

[34] John McCredie, *INIS-mf—12932: Ontario Hydro's Nuclear Program Design and Construction Status*. (Ontario: Canadian Nuclear Association, 1984), 12-13.

not the official histories that have the most developed historical timelines but the published reports of AECL, CNA (Canadian Nuclear Association), Ontario Hydro, and the government of Ontario (herein referred to collectively under the term 'technical publications') and their accompanying lectures. AECL, in particular, published a prodigious number of histories of CANDU, both in standalone articles and interwoven into most other technical publications.

Technical publications typically lack historical analysis, but they are invaluable for establishing timelines, sequencing events, and publishing interdepartmental information that would otherwise be inaccessible. All AECL and Ontario Hydro technical publications benefit from their authors being Canada's most knowledgeable people on nuclear energy and CANDU. AECL employees often publish alongside Ontario Hydro workers, combining the theoretical and practical knowledge of CANDU. All AECL publications were available for purchase by the public or libraries, which would later detract from the various anti-nuclear groups' overarching arguments of inequitable information distribution practices. With Sims as the exception, technical publications were the only scholarly pro-nuclear sources that engaged directly with the public and the growing discourse surrounding nuclear power.

Wilfrid Eggleston's *Canada's Nuclear Story* (1965) and Robert Bothwell's *Nucleus* (1988) are of the highest quality among the few sweeping works. In comparison, Gilles Sabourin's *Montreal and the Bomb* (2021) is of a lesser quality than Eggleston and Bothwell. Where Sabourin did provide unique archival material and fresh insight as a trained nuclear expert, it is immediately called into question due to his lack of proper footnote and endnote documentation and overall poor construction. Sabourin also accidentally fell into the stereotype of focusing only on the novel and innovative portion of CANDU's history. A phenomenon that will be discussed at length herein. Eggleston is unique in having written the first macro history of

CANDU, incorporating both technical and political details that contributed to the design philosophy and trajectory of CANDU. Bothwell continued this tradition by including, in new detail, nearly everything of note in Eggleston and expanding the timeframe from 1965 to 1988. *Nucleus* was of a high historical quality and veracity.

Additionally, both Eggleston and Bothwell lacked true theoretical frameworks or overarching analysis. The works are simply factual. This can be explained in three parts. First, Eggleston and Bothwell were hired by the then-presidents of AECL to produce a corporate history of AECL with particular emphasis on CANDU. Naturally, when writing a corporate history, one would shy away from being overly critical or overly theoretical in their writing. Additionally, Bothwell made very little mention of the growing anti-nuclear factions in Canada as to present a homogenously positive public attitude for this very reason. Eggleston wrote before the Canadian anti-nuclear groups formed and is excused from this criticism. The purpose of Eggleston's and Bothwell's monographs was not to contribute to the growing theoretical literature of the history of science but to produce a historically sound corporate document. That their works aligned with the overwhelming rise in uncritically positive Progress narratives of the twentieth century should be no surprise. Second, Eggleston had no formal training as a historian, in addition to being the first to attempt a macro history of AECL/CANDU. His possibly coincidental alignment with growing post-modern interpretations of technology can be largely excused. Third, while Bothwell is an eminent historian, his area of expertise is not science or technology. *Nucleus* is largely political in content, which is his area of expertise, and science and technology play secondary and tertiary roles in the narrative—mainly mentioned whenever it is pertinent to his overall political narrative. Combining both Bothwell's purpose (a sanctioned corporate history) with his penchant for politics, the content of *Nucleus* is a standard corporate history that happens to be about science and technology. Not a pure history of science and technology. Bothwell's contribution to the growing post-modern literature of CANDU results from the rising trend of post-modern interpretations of science and technology in the closing years of the twentieth century. This analysis begins by fully understanding what these post-modern notions of Technology and Progress entail, as it is the author's view that the two are inextricably linked.

Chapter One details the conflict and consequences between post-modern and modern theories of technology. Post-modern theories of technology are a symptom of a broader issue in the popular conception and study of the history of technology. Due to the exponential rise of post-modern theories, the detrimental conflation of technology and Technology arose, which guided the profession in the wrong direction. Giving rise to erroneous conceptions such as nuclear power is the defining tool of the government to enshrine itself in irrevocable autocratic powers. This view was popularized in Canada by philosopher George Grant and is critiqued throughout the chapter. Additional post-modern theories, such as an iteration of Foucault's governmentality thesis, are juxtaposed with modernist rebuttals.

Chapter Two details the realities of the technological life cycle. Integral to functioning technology is the process of 'success through failure.' Engineer Henry Petroski widely popularized this term. Petroski argued that technology is not a sudden success through metaphysical innovation, invention, or Progress. But a tangible process of how technology fails multiple times before it becomes widely serviceable. This chapter combats the notions established in Chapter One that the only period of consequence to study a given technology is its beginning stages. The source basis of Chapter Two is primarily Technical Publications and archival sources that further support the idea of success through failure. Chapter Two additionally establishes the base rebuttal to post-modern risk theorists discussed in Chapter Three.

Chapter Three discusses the opposing sides of risk theory, qualitative risk and quantitative risk. Qualitative risk theory is a post-modern notion that combines all the aforementioned qualities of post-modern theory and applies it to risk management and theory. Under qualitative theories of risk, there is absolutely no allowance for risk. If complete infallibility cannot be guaranteed, then the technology must be discarded or research ceased. This notion is fundamentally hostile to success through failure and ignorant of how technology functions in daily life. Quantitative theories of risk follow a realist-modernist belief that technology is nothing but a tool, and no matter how rigorous a tool is tested, errors and safety issues will remain. Thus, for any technology or tool to ever be produced, some amount of inherent risk must be accepted. Success through failure and test data are the main tools of realists when producing and refining technology. Chapter Three is the most extensive chapter and incorporates a mixture of unique primary and secondary sources while building off all the sources used in Chapters One and Two.

Chapter One

It has been established that under the prevailing post-modern framework of the interpretation of technology, literal technology is now conflated with the metaphysical concept of Technology. This conflation has serious implications in the historiography of science and technology as well as tangible effects on society's overall interpretation of technology. The definition of technology rapidly changed from its earliest definitions to its sudden rise in the circles of the nineteenth-century educated elites to the explosion of the term as commonplace in the early twentieth century. Technology was originally derived from *Techne*, the art of craft/craftmanship, and *Ology*, a branch of learning, becoming a branch of learning dedicated to physical crafts.[35] This definition has remained in vogue with the modernists of technology. They insist that technology itself is inherently neutral and simply a tool of humans to be used however the individual deems fit and carries no external symbolism.[36] John Stuart Mill's influential support of this interpretation is one of necessity. Within Mill's interpretation of why technology is produced, select superior humans expand knowledge further and produce increasingly widely needed and applicable technologies for the masses.[37] Technology is an essential tool to provide comfort for the people of society. The technology itself has no agency of its own as it was created for a specific purpose and did not design its purpose itself.

This original literal meaning, c. 1820s-1840s, was divided into two subsections. Technology could only advance Ideologically, change the overarching methods of the mechanical discipline, or Substantively change the literal machinery itself.[38] These sub-

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[35] Marx, "Hazardous," 562.
[36] Marx, "On Heidegger's Conception," 640.
[37] John Stuart Mill, "Elucidations of the Science of History," in *Theories of History: Readings from Classical and Contemporary Sources* (New York: Free Press, 1967), 92.
[38] Marx, "Hazardous," 564.

definitions are directly related to the technology itself, either the methods of using it or the design itself. There is no notion that technology can affect anything outside of itself as a symbol. Technology quickly lost this meaning as it was co-opted by the growing influence of post-Enlightenment Progress. Technology began as a lesser-used synonym of machinery to denote a more extensive system, such as the railway system or telegram network.[39] This dynamic reversed once technologies such as the railway system achieved widespread adoption in North America. Continuing with the railway system as the main example, prior to this period in industrial development, machinery was typically relegated to a single occupation of space and readily perceived physical object.[40]

E.g., a power loom would occupy a small enough space to be housed in a single room and seen in its entirety with a few glances. The ability to perceive the entirety of machinery was lost with emerging concepts such as the railway system. The railway system not only included locomotives, cars, and tracks in the immediate vicinity but also expanded across the entire continent, operated by thousands of workers ranging from bridge engineers to conductors. The various production capital for the parts and salaries of the employees were provided by large corporate entities or wealthy individuals looking to leverage their spending into further gains. National changes had to occur, such as the standardization of time zones and the adoption or shunning of uniform railway track gauges between various companies to either foster or prevent cooperation. This intricate system between corporations and thousands of employees across vast areas working towards a singular goal was something unprecedented before the Industrial Revolution. It was a vast socio-technical system aptly called technology.[41] It must be stressed

[39] Marx, "Hazardous," 565.
[40] Marx, "Hazardous," 567.
[41] Marx, "Hazardous," 567-568.

that technology was no more than a tool during this period. Technology was the natural expansion of human nature to produce ever increasingly effective tools. This is the modernist notion of technology. Technology is no more than a tool that humans use to achieve an end goal. An inert, inanimate object that cannot have any agency of its own or intentionally produce any effect outside itself. The railway system could not have intentionally produced the consequence of continental capitalistic expansion because it does not have any agency or will outside what humans choose to use it for.

However, technology was undeservedly and falsely subsumed into the rapidly growing ideology of capitalistic expansion via science and technology. As inventions such as the railway system linked the North American continent, technology took on a new meaning as the driving force of Progress. Railways made the rapid expansion of goods and services possible, as well as the exploitation of natural resources on a scale previously unimaginable. The fundamental fact that technology is a mere tool and not the actor choosing its implementation was forgotten. Instead of capitalistic or political actors being symbolically linked to growing notions of Progress, technology itself was.[42] Technology, the neutral tool, was mainly gone by the 1840s. Technology had become inextricably linked to post-Enlightenment Progress, capitalistic gains, and exploitation of natural resources and workers. This led to Martin Heidegger declaring that "… the essence of technology is by no means anything technological."[43] This new essence had far-reaching consequences for technology. It spurred thinkers such as George Grant to lament that as Canada and America became more technological societies, they were approaching a

[42] Marx, Hazardous, 564-566.
[43] Martin Heidegger, *Basic Writings: Ten Key Essays, plus the Introduction to BEING AND TIME*, David Farrell Krell, ed. (New York, N. Y.: Harper San Francisco, 1993), 311.

centralized state of technocratic governance in which technological elites marginalized the masses.[44]

Grant was also the loudest voice of the time in favour of preserving Canadian nationalism and national identity. *Lament for a Nation* is explicitly written as a swan song for Canadian identity, which, in Grant's mind, had died. *Lament for a Nation* was a highly influential book in Canadian culture. It seemed to give voice to previously unspoken fears of the nation, such as Grant's suggestion that Technology was a universal homogenizer and social leveller.[45] As this levelling process occurred, Canada would increasingly become a satellite state of America due to the simultaneous weakening of Canadian identity and increasing inability to resist the force of personality from the southern country. The final result would be a homogenous American state functioning under "tyranny."[46] Grant's writings play into the widespread fear of autocracy, centralization of power, and the role of Technology as the tool of this change. A compelling example of this fear is Ayn Rand's *Atlas Shrugged*, which appeared in 1957 and catastrophized all of Grant's soon-to-follow warnings. *Atlas Shrugged* catastrophizes that the co-opting of technology for Progress brings about a universally homogenized and poverty-stricken world. Rand and her work have been largely dismantled and forgotten by academics, but *Atlas Shrugged* was a bestseller upon publication and continues to sell well into the twenty-first century. Indicating there has always been and perhaps always will be a market for self-flagellating

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[44] George Grant, *Lament for a Nation: The Defeat of Canadian Nationalism* (Montreal & Kingston: McGill-Queen's University Press, 2005), 8-9, 52-53, 55-56. This theme can be found throughout George Grant, *Collected Works of George Grant. Volume 3, 1960-1969*, Arthur Davis and Henry Roper, eds. (Toronto: University of Toronto Press, 2005). Particularly the essays "Value and Technology," and "In Defence of North America."

[45] This theme permeates Grant's works on Technology. It can be found within the essay collections *Technology and Justice*, *Technology and Empire*, and throughout *Lament for a Nation*. Grant's position is summarized by Andrew Potter in the forward to the 40th Anniversary Edition of *Lament for a Nation*. George Grant, *Lament for a Nation*, xlv-xlviii.

[46] Grant, *Lament for a Nation*, 94.

polemics on the topic of Technology. Fear of Technology was one of the deciding factors for anti-nuclear groups to rally against Canadian nuclear energy. Grant's writing primed the nation for a technological scapegoat, and nuclear energy was a convenient target.

One issue to note within Grant's writings is his tendency to contradict himself and say he is arguing against one group when he is, in fact, arguing against another. For example, when Grant expands upon this societal homogenizer thesis, he states, "This state will be achieved by means of modern science - a science that leads to the conquest of nature. Today scientists master not only non-human nature, but human nature itself."[47] While arguing against 'modern' scientific and political thought, Grant actually disagrees with the post-modernist theories he aligns himself with throughout *Lament*, such as Rand. Modern creators of technology and scientific researchers do not believe that science or technology has a greater purpose concerning Progress. While post-modernists vehemently defend their Technology as the harbinger of human development and Progress. Grant's 'modernists' are the ones feeding the narrative of Progress and co-opting technology for sociocultural purposes. While in reality, technological modernists are vehemently against Grant's 'modernists,' while Grant says they are one and the same. This is an apt example of the muddiness of Grant's theorizing in *Lament for a Nation*. Grant frequently invokes grand statements and then later offers another that contradicts or obfuscates the meaning of the original. Does Grant have a problem with his self-styled 'modernists' who, in reality, are post-modernists? Or does he take issue with pieces of each school and apply labels as he sees fit? This pattern reoccurs in most post-modern texts concerning technology. As shall be shown multiple times throughout this essay, post-modernist thinkers do not care to reconcile these contradictions in their theories. As long as they have a talking point to hold on to, they will not waver, no matter

[47] Grant, *Lament for a Nation*, 52.

the amount of contradictory evidence due to entrenched heuristics, which is the focus of Chapter Three.

Grant's technology essays and *Lament for a Nation* all appeared during the heyday of nuclear power in Canada. Alongside the publications, public distrust and malcontent with nuclear were steadily growing. Rising apprehension cemented the new public perception of nuclear power. Nuclear power was perceived as the beginning of a centralized technocratic state in which all policy was undertaken by experts using technical language the lay population could not understand.[48] These fears were echoed by the post-modern followers of Foucault's governmentality thesis. Foucault's pure governmentality thesis actually had nothing to do with technology but rather was about systems of government control over culture and society. This notwithstanding, it was quickly amalgamated with the overarching ideas of post-modernism.

Foucault argues the Prince's (whomever or whatever has obtained power, intentionally invoking Machiavelli's Prince) methods of obtaining power do not matter; violent, legitimate, or illegitimate, no matter the way in which it is obtained, it will always remain "synthetic."[49] Meaning the Prince's authority will always be open to question and resistance from its subjects.[50] As a result, the Prince's primary relationship is not with other powers or whatever assisted them in obtaining power but with "… what he owns, with the territory he has inherited or acquired, and with his subjects."[51] This relationship is exemplified by Canadian nuclear power. Crown corporations were created with no input from the public (the Prince inheriting their power, in this

[48] Grant, *Collected Works Vol. 3,* "Value and Technology," 227-229.
[49] Michel Foucault, "Governmentality," in *The Foucault Effect: Studies in Governmentality*, Graham Burchell. Colin Gordon, and Peter Miller, eds. (Chicago: University of Chicago Press, 1991), 90.
[50] Foucault, "Governmentality," in *Foucault Effect*, 90.
[51] Foucault, "Governmentality," in *Foucault Effect*, 90.

case, literal power) and grew in size to eventually be commanding over half of Ontario's energy production and was forecasted to provide the entirety of Ontario's energy eventually. Resistance from the outside arose, such as activist groups wanting energy alternatives to nuclear energy. This want for the replacement of nuclear energy will be highly relevant in Chapter Three. Nuclear was the incumbent Prince of Ontario energy generation, and rival Princes began warring to siphon off the power and influence of nuclear energy.

Simultaneously, the people, the subjects of Ontario, had no reason to accept nuclear as their new Prince. Hydroelectricity, coal, oil, and gas had served Ontario well for decades. Why would the public need to change their opinions because a crown corporation they did not ask for began radically shifting the energy network? Leading naturally to the conclusion of the first part of Foucault's metaphor, the Prince must shift their focus to maintaining and reaffirming their relationship with "what he owns, with the territory he has inherited or acquired, and with his subjects."[52] By the 1980s, CANDU reactors were situated in Bruce County (the largest nuclear site in the world, achieving criticality throughout the 1980s), Pickering, and Darlington. The latter two are densely populated cities and all on the shores of the Great Lakes. Both Pickering and Darlington nuclear-generating stations were in the 500 MWe range. Darlington would meet numerous delays due to the lingering effects of the debates of the 1980s and would achieve criticality during the 1990s. As a result, it is not a point of focus of this study but a consequence of what is discussed here within. On a basic level, the communities had not asked for nuclear plants to be constructed in their towns, just as one does not ask for a Prince to usurp their predecessor. AECL, a crown corporation, as literally and metaphorically close to Machiavelli's Prince modern Canada can come, had upset the balance of energy distribution in Ontario, bought

[52] Foucault, "Governmentality," in *Foucault Effect*, 90.

large parcels of land, built nuclear reactors, and forcefully integrated themselves into local populations. This naturally fulfilled the other half of Foucault's argument that rivalling entities would attempt to usurp the incumbent entity, nuclear energy, just as it had usurped control from its predecessors, hydroelectric and fossil fuels.

This framework works to a degree. What it does not take into account is that the evolution of energy production in Ontario was a mere technological change. There was no "violence, through family heritage or by treaty, with the complicity or the alliance of other princes."[53] Foucault dismisses the absence of any/all of these prerequisites as irrelevant.[54] However, there is a fundamental disconnect in the theory when applied to technology. Post-modern followers of governmentality who apply the framework to nuclear energy are ascribing agency to technology. Which, as discussed, it does not possess. While a metaphorical Prince can actively usurp power and maintain a relationship with lands/people, technology cannot because it is not an agent. Technology is a tool for humans to wield as they see fit. Within the creation and expansion of CANDU, there was no intent to seize power through violence or any of the means outlined by Foucault. For example, in the technical publication *AECL-6351*, author G. A. Pon outlines the evolution and targets of CANDU from the NPD reactor to DPGS. Within the evolution and iterations of design, the only goals are increased efficiency, reliability, lower maintenance, and increased power output.[55] These goals simply pursue an increasing effectualness as a by-product of pursuing the mandate of producing safe and reliable power. The program moved forward by solving practical problems such as leaking heavy water from steam

[53] Foucault, "Governmentality," in *Foucault Effect*, 90.
[54] Foucault, "Governmentality," in *Foucault Effect*, 90.
[55] G. A. Pon, *AECL-6351: Evolution of CANDU Reactor Design*. (Chalk River: Atomic Energy of Canada Limited, 1978), 1-11.

valves.[56] On the ground level, engineers solved problems, and there were zero machinations of broad power.

Post-modern theories of Technology tend to ignore the reality in which technology is produced and maintained. The beginnings of CANDU were to provide an economic service to avoid the crown shutting down nuclear research due to a lack of results. A. J. Mooradian was blunt in expressing this reality during a conference. Stating CANDU started under the romantic notions of pure science but matured into a harsh economic reality.[57] This sentiment was echoed seven years later in 1971 during a United Nations conference on peaceful uses of atomic energy. Presenters R. G. Hart, L. R. Haywood, and G. A. Pon (all technical experts on CANDU design and evolution of design) included a bitter aside that attractive nuclear prototypes had been cancelled due to growing economic standards and "commercial exploitation."[58] These prototypes include the OCR, BLW, CANDU-3, and CANDU-9. All of which will be detailed below and within Chapter Two. Once CANDU had reached commercial capabilities after Douglas Point, it had, due to the process of success through failure, become one of the cleanest and safest energies produced in Canada. This is economically, environmentally, nationally, and politically enticing for proliferation.

By the time the Pickering and Darlington nuclear stations were greenlit, it was projected Ontario's energy needs would grow between 2-6% (with an average of 4%) per year from 1978-2000.[59] With CANDU reactors growing from 3,800 MW in 1977 to a projected 10,000 MW in

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[56] Pon, *AECL-6351*, 11.
[57] Mooradian, *AECL-1985*, 1.
[58] R. G. Hart, L. R. Haywood and G. A. Pon *The CANDU Nuclear Power System: Competitive for the Foreseeable Future*. U.N Peaceful Uses of Atomic Energy Conference. Sept 6-16, 1971. Vol. 5., 241.
[59] *CA2ON-Z1-756002. Royal Commission on Electric Power Planning: Interim Report on Nuclear Power in Ontario: A Race Against Time*. Presented to Minister Rene Brunelle, 12 September 1978. XI.

2000.[60] This high-pressure environment led to a concentration of resources on proven technology (CANDU-6, the standard CANDU model) rather than investing in new avenues. These decisions were made by AECL, Ontario Hydro, and the Federal and Provincial Governments. In other words, state agencies that had existed for decades and in no way fit the theory of an upstart Prince having to maintain control over their tenuous relationship with their subjects. CANDU itself had no role in these decision-making processes because it could not. To labour under the notion that technology with no agency could execute a usurpation of power in the energy sector is misguided. By the 1960s to mid-1970s, CANDU had progressed scientifically and technologically to the point where it was naturally placed as the next step in provincial energy planning. There was no grand conspiracy of nuclear cutting out rivals based on political machinations instead of merit. Post-modern followers of governmentality were misinformed of the nature of technology and technological evolution from the beginning.

Foucault furthered the metaphor by stating that the Prince must rule with wisdom and diligence.[61] Foucault's wisdom and diligence are not of the traditional form but rather the wisdom of where to guide society and the diligence to do so with the best interest of the subjects in mind.[62] However, these noble intentions had been overshadowed by growing fears and distrust of power structures. George Grant had planted the seeds of fear that the growing technocracy was seeking to subsume the public into a homogenous mass, thus perverting one of the innate goals of the state.[63] As the gap between the lay population and those communicating advancements in nuclear science grew, so did the fear of obfuscation of the goals of the state.

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[60] *CA2ON-Z1-756002*, Minister Rene Brunelle, XI.
[61] Foucault, "Governmentality," in *Foucault Effect*, 96.
[62] Foucault, "Governmentality," in *Foucault Effect*, 96.
[63] Grant, *Lament for a Nation*, 52-53, 55-56.

When fear and distrust are mixed, it is easy to doubt the intentions of the state. This holds especially true when combined with the other prejudices against nuclear energy from the post-modern belief system. Foucault also warned of this perversion of state power within his governmentality theory. Stating the modern state was operating under classical notions of reason but had altered them into powerful systems of oppression.[64] Warning the public that the state had its own unique form of rationality the public could not understand.[65] These warnings are so reminiscent of Grant that they could have been written in tandem.

A crucial section of Foucault deserves to be quoted in full as it elucidates a core tenet of post-modern ideology:

> … population comes to appear above all else as the ultimate end of the government. In contrast to sovereignty, government has as its purpose not the act of government itself, but the welfare of the population, the improvement of its condition the increase of its wealth, longevity, health, etc.: and the means that the government uses to attain these ends are themselves all in some sense immanent to the population; it is the population itself on which government will act either directly through large-scale campaigns, or indirectly through techniques that will make possible, without the full awareness of the people, the stimulation of birth rates, the directing of the flow of population into certain regions or activities, etc. … aware, *vis-a-vis* the government, of what it wants, but ignorant of what is being done to it. Interest at the level of the consciousness of each individual who goes to make up the population, and interest considered as the interest of the population regardless of what the particular interests

[64] Foucault, "Governmentality," in *Foucault Effect*, 96-97.
[65] Foucault, "Governmentality," in *Foucault Effect*, 96-97.

> and aspirations may be of the individuals who compose it, this is the new target and the fundamental instrument of the government of population: the birth of a new art, or at any rate of a range of absolutely new tactics and techniques.[66]

Foucault has succinctly provided a core argument as to why post-modernists are suspicious and fearful of governmental activity. Post-modernism believes the state is a fundamentally unjust system that does not aim to serve its constituents as it did centuries ago. Naturally, post-modernity is suspicious of states that exert strong control over aspects of the lives of the populace. However, governmental states that operate a national framework to support the welfare and advancement of their citizens are fundamental tenets of the modern liberal state. Within a just liberal society, the average citizen does not need to fear being ‘ignorant’ of every decision made by the government. Citizens can focus on living their lives and fulfilling their needs without being constantly paranoid about state agents working against them. Yet, this is the society writers such as Foucault thought the West had become and George Grant, Canada. Their states had devolved into homogenized technocratic states that exploited their citizens for unknown goals. As neo-liberalism and liberal individuality rapidly evolved in the latter half of the twentieth century, the acceptance of state intervention/policy for the good of the people over the potential good of the individual was decried.

Governmentality posits that as Western society increasingly adopts neo-liberal ideology, the responsibility of society is less the purview of state agencies and increasingly on the individual.[67] States are decreasingly involved in the lives of individual citizens, and the power of the individual over their safety and sovereignty is increasing. Foucault’s writings on

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[66] Foucault, “Governmentality,” in *Foucault Effect*, 100.
[67] Deborah Lupton, *Risk* (New York: Routledge, 1999), 88.

governmentality speak of an increasing gap between state experts and the individual.[68] This expert knowledge is then subsumed into the popular consciousness through the process of Normalization. Normalization is the taken-for-granted acceptance of state actions such as mass surveillance and data collection.[69] Foucault argues that the state then uses these normalized data points to impose its will onto the public with or without its consent and that the public is willingly obliging under the social contract.[70] Herein lies a flaw in the logic of governmentality's argument. Within its thesis, it is argued that the public either willingly or unwillingly and unwittingly participates in this system. In the words of Deborah Lupton, "The strategies of governmentality, expressed in the neoliberal states that emerged in the west in late modernity, include both direct, coercive strategies to regulate populations, but also, and most importantly, less direct strategies that rely on individuals' voluntary compliance with the interests and needs of the state."[71] This theory is notably weakened under scrutiny. Arguing that explicit government policies of control are indicative of governmentality is sound. However, the assertion that implicit controls exist without public knowledge or participation, thereby beyond definition or categorization, is perhaps too tenuous. If systems of government control are visibly working to control the population, governmentality is confirmed. If these systems are invisible and have no explicit impact on society, governmentality is still confirmed. This is simply the 'argument from ignorance' fallacy applied to sociocultural theories of risk. Knowing these if/else statements to be false as governmentality has not been explicitly documented to be influencing Western society, it holds that it is theoretically false. However, this simple explanation as to why governmentality

[68] Lupton, *Risk*, 88.
[69] Lupton, *Risk*, 89.
[70] Lupton, *Risk*, 89.
[71] Lupton, *Risk*, 89.

does not offer convincing evidence has not stopped it from becoming favoured in post-modern theory.

Foucault's thesis was subsumed by the post-modern theorists and applied to Technology and risk. For governmentality relativists, the risk was sociocultural and produced by groups of individuals operating 'safely' under government systems.[72] As Chapter Three will demonstrate, governmentality mutated from governing bodies exerting control over the population to the individual calling for control over the population in the interest of their personal rights. Governmentality was also caught in the influence of Grant's theories of Technocracy, and increasingly, activists felt that Technology was an oppressive and unwanted tool of government overreach. Technology was increasingly seen as a tool of control for state bodies, combined with the fear of the rift between lay and expert knowledge becoming irreversible. Nuclear energy was a highly publicised, government-funded crown technology and was constantly in the public eye due to rapid expansion in Ontario. Uniquely advanced in its technological design, it was difficult for the lay population and experts to discuss basic components beyond atomic fission. This confusion and accusation of obfuscation would surround nuclear energy for the remainder of the twentieth century. Making it a convenient target for accusations of Technocracy and governmental foul play.

Nuclear power was not only socially dangerous as the harbinger of this new society, but it was also seen as physically dangerous.[73] As hysterics grew around a nuclear society, baseless claims surrounding the dubious safety of the plants emerged.[74] The post-modern symbol of

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[72] Lupton, *Risk*, 26-27.
[73] The perceived physical dangers of nuclear power are discussed at length in Chapters 2 and 3.
[74] Gordon H. E. Sims, *The Anti-Nuclear Game* (Ottawa: University of Ottawa Press, 1990). The entirety of the book deals with this subject and will feature prominently in Chapter Three.

nuclear reactors as dangerous, against public interest, and a polluter had permeated society. Martin Heidegger termed this shift in vast public perceptions as a shift in *gestell*.[75] Which means the frame in which humans build their various perceptions of the world.[76] As the fundamental notions of technology morphed into metaphysical Technology with its unique symbolic attachments, the common *gestell*, or way of seeing reality, changed. Previously, nuclear reactors were seen literally and positively because this is how the modernist designers marketed the product. The modernist interpretation was the only one put forth in the beginning, so it was naturally adopted until competing theories of post-modernism emerged in post-war Canada. Organized and widespread resistance to nuclear energy did not form until the 1960s-1980s, which coincides with the proliferation of both Grant's and Foucault's/post-modern governmentality theories of Technology. Nuclear energy was introduced as a domestically produced and manufactured energy technology that could make Canada independent of American energy imports. Safety was perceived as acceptable, and the technology received very little attention. But after the rise of post-modern symbolism attached to nuclear energy during the 1960s and 70s, for example, due to the increasing notoriety of Grant's and Foucault's theories within Ontario, the public began changing their *gestell* of nuclear as both an alternative energy source and its safety. One cannot easily look outside their personal *gestell* as it encompasses the entirety of how they interact with the world.[77] Pro-nuclear advocates by the late 1970s were forced to work against an increasingly ingrained public perception and prejudice until another shift in *gestell* occurred. This potential shift in *gestell* was absent until the 2020s—an intriguing time for Canadian nuclear energy that will offer this paper's *coda.*

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[75] Heidegger, *Basic Writings*, 325.
[76] Heidegger, *Basic Writings*, 325-327.
[77] Heidegger, *Basic Writings*, 325.

Gestell is a core concept for historians of technology. Within the nuclear power example, the proliferation of nuclear power is not simply a technological advancement but astounding Progress. Humans have exploited a fundamental reaction of the universe at will. Nuclear Power had gone beyond a simple power technology and had become a symbol of humankind's domination over nature. Technology is also a cultural phenomenon to its detriment. While pursuing technological advancement, nuclear technology unintentionally became a lightning rod for disagreement over humans' place in religious debates, the natural world, and social structures. This perceived transgression of humans' place in the world formed a sizeable portion of the resistance to nuclear power, discussed in Chapter Three in particular reference to Bertell and Lovins. Nuclear energy, as an unwitting example of Progress, was targeted as the prime example of an unjust governmental ploy. This antagonism forms the foundation for Chapter Three.

The gap between technology and Technology appears readily in the historiography of CANDU, with failures relegated to obscurity. Gordon L. Brooks, a chemical engineer and AECL manager, presented a truncated, comprehensive technical history of CANDU in 1993. This short document is the natural bridge between Bothwell's superb political history and Hurst's unimpeachable technical accuracy. Despite no historical background and a constrained word count, Brooks produced a technically and historically accurate history of CANDU from 1942 to 1993. The most important aspect of Brooks' work is that he dedicates chapters to the two failed prototype CANDU reactors, the CANDU-3 and CANDU-9. Shortly after Brooks's report, both projects were cancelled and never mentioned in detail within the literature again.[78] Supporting

[78] The last official AECL reference to CANDU-9 as an ongoing project was R.S. Hart's 1994 conference lecture, later published as R.S. Hart, *The CANDU 9* (Proceedings of the Canadian Nuclear Association 34 Annual Conference, Canada, 1994).

Edgerton's assertion that technology has become conflated with innovation and invention. When CANDU-3 and CANDU-9 were potential markers of intense innovation, they were championed as the future of nuclear technology.[79] Following their cancellations, they were relegated unceremoniously to the dustbin of past projects.

Hurst's *Canada Enters the Nuclear Age* contains the most in-depth and widespread store of information on the evolution of CANDU's technological aspects. Yet neither Hurst nor the 16 contributors mention CANDU-3 or CANDU-9 in detail. CANDU-3 is mentioned once by contributor H. K. Rae in passing, yet Rae refers to it as a promising ongoing project despite having made zero sales in eleven years (1986-1997) on the market.[80] Should two projects that cost millions of dollars, diverted resources away from the successful CANDU-6, and made zero sales over their operating lives be championed as Progress? Within the post-modern world, yes. Within the increasingly post-modern literature of the history of technology, it is increasingly irrelevant if the technology actually succeeded in its intent. What matters is that it was there at the bleeding edge of some long-sought-after dream of Progress. While the process of failure is essential for technological advancement (see Chapter Two), for these major projects to be cancelled and forgotten within the literature is a symptom of the larger issue. To learn from failures, the failures must be remembered and studied. There is zero educational or technological benefit from failing and then forgetting why and how that failure occurred. The proliferation of Post-Modern theories and *gestell* are fundamentally opposed to the success and improvement of technology.

[79] CANDU-3 and -9 had been regularly mentioned in technical publications from their inception to their abrupt end with Hart's publication.

[80] H. K. Rae in Hurst, *Technical History,* 202.

Within Hurst's edited collection *Canada Enters the Nuclear Age*, R. G. Hart, an AECL chemist and administrator, wrote a dedicated chapter to the two largest failed CANDU projects. The Boiling-Light-Water (BLW) and Organic-Liquid-Cooled (OCR) Reactors. This chapter is an enlightening addition to the historiography of Canadian nuclear energy as it is the only work tracing the development cycle and cancellations of these projects. For the only full study of these failures to appear in a technical history with no input from historians of technology supports the theory that the history of technology and histories of Technology are branching in opposite directions. Bothwell is the only historian to mention these two reactors, choosing to focus solely on the political factors involved in obtaining approval of the two projects and the political reasons for their abandonment. *Canada Enters the Nuclear Age* was produced entirely by technical experts with zero historian involvement. Yet, it is the single piece of CANDU history that goes into any appreciable detail about the failed projects. The splintering of focus due to expanding post-modern views of technology is causing appreciable shortcomings in the Canadian nuclear energy literature. The shortcomings of the BLW and OCR literature will be addressed fully in Chapter Two, in addition to the role of failure in technological advancement.

Chapter Two

The previous section focused on theories of technology/Technology, but now the focus turns to how technology is actually designed and evolves in the world beyond theory. To begin, John Foster, former president of AECL, offered an anecdote during a symposium of how a major technical decision was made for CANDU during the first decade. Pressure tube reactors feed fuel from an outside fueling machine and require an absolute seal with the interior pressure tube to ensure no errors occur during the fueling process. By the 1950s, France's EL4 reactor employed a complex system of both a screwed and brazed joint, and an electron beam, increasing the potential risk of malfunction with each additional piece.[81] However, this was the most technologically advanced system at the time. Meanwhile, AECL decided to use a simple rolled joint, which had been used in machinery for over a hundred years to connect boiler tubes and drums. At the time, when asked why this decision was made, Foster quipped, "lack of imagination," and the design decision has remained in CANDU reactors since.[82] While very few design choices were actually as flippant as Foster portrays, it is a refreshing juxtaposition from the convoluted post-modern theorizing of how technological decisions are made. The purpose of this chapter is to detail how and why design decisions are made, specifically within CANDU, and how they support the modernist scientific interpretation that technology is not an agent and cannot pursue objectives outside of itself.

A central tenet in the philosophy of technology production is success through failure. Henry Petroski is one of the most famous proponents of this theory. Petroski states that desire

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[81] John Foster, *CA9500867: The Development of Nuclear Power* (Toronto: Canadian Nuclear Association and Canadian Nuclear Society, 1989), 49.
[82] Foster, *CA9500867*, 49.

and imagination are the prime movers of technological advancement.[83] What Petroski means is that humans are never satisfied with a system if it performs under their expectations and goals. Naturally, this leads to the next step of isolating the point of failure/underperformance and finding a solution.[84] Focusing on points of failure and fixing them is the soundest progression of events when producing technology. Past success cannot and never should be relied on as a promise of future performance because success can mask failures.[85] If within a system functioning 'well,' engineers removed their focus from advancing the technology or fixing current issues, the system would eventually experience a catastrophic failure that was not prepared for or can be fixed. Petroski uses the example of rock hammers. If a particular type of rock had always been used as the 'hammer' rock and no effort was made to find new types of hammers or find a way of hardening the 'hammer' rock, eventually, it would be used against a material that would shatter it—leaving the user with neither the hammer nor the wanted material. Past success does not guarantee future success.[86] Focusing on and fixing failures produces an increasingly sound system over time while focusing on success does not offer any feedback. A system can never reach perfect durability, but it can be made increasingly resilient to failure. This increased resilience, combined with increased efficiency, is the ultimate goal of iterative engineering and design. As will be shown throughout this chapter, this was the explicit goal for CANDU within AECL and Ontario Hydro.

Two leading theories of how this design evolution emerges exist. First is slow, nearly linear progress resulting from consistent and diligent research and testing. Second, Thomas Kuhn

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[83] Henry Petroski, *Success Through Failure: The Paradox of Design* (Princeton: Princeton University Press, 2018), 12. EPUB.
[84] Petroski, *Success Through Failure*, 12
[85] Petroski, *Success Through Failure*, 13.
[86] Petroski, *Success Through Failure*, 13-14.

introduced the paradigm shift concept in 1962. Beginning with the gradual theory. Science and technology were thought to progress roughly linearly regardless of their environment. The comparison to biological evolution is commonly invoked by arguing that evolution does not have sudden leaps in complexity but slowly iterates upon itself over vast swathes of time.[87] Just as evolution progresses constantly on a global scale, so do science and technology. Manifesting itself in the historical pattern of multiple groups of scientists reaching the same breakthrough at roughly the same time.[88] This theory is technological determinism. Similar to biological determinism, it is thought that technology will continue to advance/evolve no matter the actual effort or quality of human input. Technological determinism is inextricably linked to the idea of historical Progress, which has been suitably resisted above and elsewhere.

Meanwhile, Kuhn's theory of paradigm shifts emerged as a direct counter to technological determinism. The theory has been highly influential to not only science and technology but the world at large. 'Paradigm' and 'paradigm shift' entered the common language after the publication of his work *The Structure of Scientific Revolutions*. Kuhn's theory of paradigms follows that all work within a scientific/technological discipline and all research/development follows a 'paradigm,' or overarching set of established theories and rules that limit what can be achieved within these overarching rules.[89] Kuhn argues that the progression of knowledge can only advance so far under a false paradigm as researchers are

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[87] Robert Heilbroner, "Do Machines Make History?," *Technology and Culture* 8, no. 3 (1967): 337-338.
[88] Heilbroner, "Do Machines Make History?," 337. See also Richard Rhodes, *The Making of the Atomic Bomb* (London: Simon and Schuster, 1986, 2012). Rhodes heavily utilizes this theory in the opening third of his book. The book is also a decisive history of the progenitor of American nuclear energy. Canadian counterparts can be found in Eggleston and Bothwell, who have already been covered here.
[89] Thomas Kuhn, *The Structure of Scientific Revolutions, Third Edition* (Chicago: University of Chicago Press, 1996), 7, 15, 18-19.

labouring under false premises and, therefore, cannot reach true fact.[90] The trajectory of Kuhn's theory is one of exponential growth, followed by growth in fits and starts until it stagnates, as no further growth under the current paradigm can occur. The ineffectual paradigm is then discarded, and its theories and rules are subsumed into the new paradigm, regressing knowledge back to a more basic state before repeating the cycle. This is Kuhn's paradigm shift, which can be visualised as two steps forward and one step back. Kuhn stresses that old theories and held 'truths' must be discarded upon the adoption of a new paradigm.[91] This is Kuhn's rebuttal to technological determinism and the idea that linear progression is possible or even wanted. An important aspect of Kuhn's theory that will be extremely relevant within Chapter Three is those who do not abandon the old paradigm and remain stalwart supporters. These individuals refuse to update their beliefs and adopt the new rules and system of the new paradigm and are spurred by the institutions and former colleagues. These individuals are forced to align with a different group, resisting the paradigm or proceeding in isolation.[92] Paradigm shifts are the theoretical model which makes progress possible.

Kuhn's theory is the ultimate and metaphysical success through failure. For progress to occur, the emerging paradigm must consume and discard an old paradigm. Resulting in temporary setbacks in the field/project but ultimately results in success beyond the previous ceiling of research. This is success through failure expanded to the metaphysical. A technological failure, such as fueling machine errors, results in repeated reactor failures, eventually leading to a fuelling machine system that is known to rarely ever fail before its operating lifespan is up. This is precisely what occurred during the early operating days at Douglas Point Generating Station

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[90] Kuhn, *Scientific Revolutions*, 7-19.
[91] Kuhn, *Scientific Revolutions*, 7.
[92] Kuhn, *Scientific Revolutions*, 18-19.

(DPGS). The DPGS fuelling machines arrived on site ready to be immediately installed and operated during the standard online and offline power cycling system. The fuelling machines were not designed or equipped to handle DPGS's online refuelling systems, meaning the reactor was never supposed to go offline like previous reactors.[93] As online refuelling had never been fully realised prior to DPGS, the engineers and builders had no procedures or experience incorporating the new paradigm. As a result, the fuelling machines had to be extensively redesigned and rebuilt once they arrived on site.[94] However, the DPGS engineers had never worked with online refuelling either, resulting in perpetual failures and issues with DPGS fuelling machines between 1967 and 1971.[95] Failures in the conventional system machinery, such as fuelling machines or boiler units produced with "special welding techniques" that collapsed upon use, would eventually account for 45% of lost operating factor (electricity produced over how many hours it had been in service, including offline hours) within DPGS.[96] This was accounted for in the planning of DPGS and was expected to last six years, from 1967 to 1973.[97]

Due to an inherent acceptance of success through failure guiding reactor design, DPGS's failures were not unwelcome surprises but expected and welcome given that DPGS's entire purpose was to be a "first design" prototype to catch these errors before the true reactors at

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[93] J. H. Armstrong, *72-CAN-301 Operating Experience at Douglas Point GS* (Chalk River: Atomic Energy of Canada Limited, 1972), 2.
[94] Armstrong, *72-CAN-301 Douglas Point*, 2.
[95] Armstrong, *72-CAN-301 Douglas Point*, 2.
[96] Woodhead *et al*., *AECL-3972: Commissioning and Operating Experience with Nuclear-Electric Station* (Chalk River, Atomic Energy of Canada Limited, 1971) 7.; C. L. Moon. *AECL-1515: Douglas Point Nuclear Power Station* Republished in *Canadian Nuclear Technology* (Spring 1962). 4.; Additionally, the Calandria piece was found to be lacking in quality upon its delivery to DPGS. The Calandria is essentially the core of a nuclear reactor and the reactor cannot function or function safely without an exacting quality piece. This is yet another example of the issues plaguing DPGS. L. J. Ingolfsrud, P. H. G. Spray, J. H. Jackson. *Manufacturing and Construction for the Douglas Point Nuclear Power Project*. Presented at the 1964 U.N Peace Conf. (New York: United Nations, 1965), 301-302.
[97] Woodhead *et al*., *AECL-3972*, 6.

Pickering were built during the 1970s.[98] Despite the plethora of issues, DPGS would increase its operating factor by 36% in 1971.[99] Additionally, DPGS ended its first year of operation with a Net Capacity Factor (NCF, net MWh generated / net rated MWh) of 42.7% and dropped to 20.7% the following year.[100] This provided essential knowledge for the construction of Pickering-1 and -2 shortly after, and both reactors achieved a first-year NCF of 80%, which continued to climb during its service.[101] Without the vital experience gained at DPGS, Pickering would assuredly not have been as successful. This experience was specifically necessary from DPGS, not NPD, which had been in service during the majority of the 1960s. This is due to Kuhn's regression theory, which states that when a paradigm changes, knowledge must take a mandatory step back or regress to a simpler stage to build itself back up. NPD achieved an NCF between 70 and 100% over the course of October 1962 to April 1964, with a total average of 82% and 90.4% between January and April 1964.[102] However, NPD was operating under circumstances far different from those of DPGS.

First, NPD had not achieved efficient online refuelling prior to DPGS going critical. Second, NPD was exponentially smaller and simpler than DPGS (approximately one-tenth the size and complexity.) The process of scaling up a nuclear reactor is exasperatingly complex and would require reworking all equations and design elements to operate under the new conditions.

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[98] Woodhead *et al.*, *AECL-3972*, 6.
[99] Woodhead *et al.*, *AECL-3972*, 6.
[100] Woodhead *et al.*, *AECL-3972*, 6.
[101] L. W. Woodhead, *72-CAN-303 Review of Ontario Hydro's Nuclear Program and Experience*, Presented at the 1971 CNA Annual Conference June 11-14, 1972. (Chalk River, Atomic Energy of Canada Limited, 1972), 1.
[102] L. W. Woodhead and W. M. Brown. *Performance and Problems of NPD*, Presented at the 1964 U.N Conference for the Peaceful Uses of Atomic Energy, 313-314.; Specifically, NPD achieved NCFs of 98% from 1st December 1964 to 31st January 1965, 75% from 1st January 1965 to 30th June 1965, 97% from 1st December 1965 to 28th February 1966, and 98% from 1st December 1966 to 28th February 1967. These numbers were not expected to be replicated in DPGS. E. P. Horton, *SM-99/27: NPD Operating Experience*, Presented at the 1967 I.A.E.A. Heavy Water Reactors Symposium, 55.

Thirdly, simply, the more complex the machine is, the more probable it is things will malfunction or break, especially if large leaps in design occur without an intermediate step. For example, CANDU designs began with 7 fuel bundles (essentially, how much power can be drawn/fuel burned from the reactor at a time) before reaching 19 in DPGS and 28 in Pickering.[103] This directly manifested itself in the achievable scale of the various reactors. NPD was designed with a 20 MWe capacity, DPGS 200 MWe, and Pickering 500 MWe.[104] Crucially, both tangibly to the reactor's efficacy and Kuhn's theory, it was untenable to produce a design jump from NPD directly to Pickering. This further affected the load placed upon each fuel channel per metre. NPD produced 0.163 MWt/m within the fuel channel, progressing to 0.453 MWt/m in DPGS, 0.752 MWt/m in Pickering, and 0.881 MWt/m in Bruce A and B.[105] This had a cascade of additional effects, such as the widening of fuel channels leading to wider pressure tubes requiring an increase in fuel efficiency and reactor size, which affects the entire system, to name only a few.[106] Jumping or 'innovating' in post-modern language, from NPD to Bruce, would have caused an unknowable number of unexpected errors and malfunctions. Simply put, large leaps in technology, just as in biology, are unlikely to produce a system in which the desired effect is adequately produced.

Additionally, it had been widely noted and publicly acknowledged by AECL that Canadian manufacturers experienced vast difficulties fulfilling the orders for DPGS while

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[103] W. B. Lewis and J. S. Foster, *AECL-3569: Canadian Operating Experience with Heavy Water Power Reactors* (Chalk River: Atomic Energy of Canada Limited, 1970) 4.; I. L. Wilson, C. E. Beynon, W. G. Morison, and N. L. Williams. *Studies of CANDU-type reactors in the 500 MWe Range*, Presented at the 1964 U.N Conference for the Peaceful Uses of Atomic Energy, 292.

[104] Bothwell, *Nucleus*, 228.; Mooradian, *AECL-1985*, 2.

[105] Pon, *AECL-6351*, 4. Gentilly-2 would reach 0.931 MWt/m, but due to its location outside of Ontario and mostly operating post-1990 it is not included within this study.

[106] Pon*, AECL-6351*, 3-4.

meeting and maintaining the level of quality necessary for safe operation.[107] These issues would have compounded catastrophically if DPGS had been skipped in favour of immediately designing Pickering. AECL was committed to their nuclear safety mandate. Outside of test or first-design reactors, these high rates of issues and malfunctions would not be tolerated. All CANDU reactors, upon full operation, would match the safety standards of other industrial plants at a minimum and outdo them in every way they could.[108] All equipment within a CANDU reactor was to have a maximum failure rate of 0.003%, and every piece of equipment was to be produced with triplicated circuits, meaning the equipment would need to fail three times to go offline.[109] Due to these stringent safety measures, there has never been a large-scale Canadian nuclear accident in commercial nuclear power plants. This is also a rebuttal to the theory of intense innovation and invention under post-modern theories of Technology. CANDU was a laboriously iterative process that progressed and regressed along unique design stages rather than the supposed intense period of invention to create a powerful Technology. Favouring a cautious and iterative process allowed AECL to overcome the various issues with CANDU before installing a widespread fleet of reactors.

Pickering greatly benefited from this approach. The NCF of Pickering Units 1-3 from 1971-1972 were benchmarked at 80% with a 10% margin of error due to projected malfunctions.[110] Unit 1 achieved an NCF of 71.9%, Unit 2 86.5%, and Unit 3 92.3%.[111] Supporting the argument that success through failure and slow iteration of design leads to greater

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[107] J. L. Gray, *AECL-1985: A Nuclear Plant Supplier*, (Chalk River: Atomic Energy of Canada Limited, 1964), 10-12.
[108] G. C. Laurence *et al*., *Reactor Safety Practice and Experience in Canada*, Presented at the Third U.N Conference for the Peaceful Uses of Atomic Energy. August-September 1964. Vol. 13. 317.
[109] Laurence *et al*., *Reactor Safety*, 318.
[110] K. L. Smith, *AECL-4357: Recent Progress with Canada's Nuclear Generating Stations* (Chalk River: Atomic Energy of Canada Limited, 1972), 13.
[111] Smith, *AECL-4357*, 9.

success in the long term. The average NCF during this period was 83.6%. On paper, this would seem to support that Pickering was barely meeting their target of 80%. This is unsupported when the data is looked at individually. However, misrepresentation via selective data will be a consistent theme within Chapter Three's discussion of post-modern resistance to nuclear energy. A long-held debate within the field of history is the objectivity of sources, particularly quantitative data, and the various ways in which it can be used to distort an event or support an ideological end. Chapter Three will focus on anti-nuclear groups who purposefully distorted quantitative data to support an explicit ideological goal, i.e., the end of nuclear energy in Canada.

Built alongside Pickering using the lessons from DPGS, the Point Lepreau nuclear station would achieve an average NCF of 90.7% between 1981 and 1991 with exponentially fewer errors.[112] An important caveat noted by Alan Nixon at the Library of Parliament Science and Technology division is that if *all* CANDU reactors NCFs, including test reactors such as NPD and DPGS, were calculated, it would fall at 73.7%, placing Canada 8th in terms of world reactor efficiency.[113] However, Nixon stresses this number includes all offline time as well as test phases during which a reactor is purposefully run at a lower capacity.[114] This is important to understand as it displays the natural trajectory of technology designed via success through failure and the teething stage during paradigm shifts. It also highlights that pure data does not always provide a clear picture of events. This cautious and incremental approach is fundamental to the ideas of success through failure, classic technological innovation and design, and Kuhn's theory of paradigm shifts followed by slower iterative change. DPGS was the first at-scale CANDU

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[112] Alan Nixon, *BP-365E. The Canadian Nuclear Power Industry – Library of Parliament Background Paper* (Ottawa, ON: Minister of Supply and Services Canada, 1993), 7.
[113] Nixon, *BP-365E*, 7.
[114] Nixon, *BP-365E*, 7.

reactor, which is why it is used as the benchmark for producing future CANDUs while simultaneously supporting Kuhn's theory. DPGS was a pertinent example of success through failures' capabilities to produce increasingly efficient and effective technology. As well as Kuhn's theory of 'growing pains' during the early stages of switching paradigms. This additionally supports the conclusion that Kuhn's paradigm theory rests on a sounder scientific base than that of technological determinism due to real-world applicability. This contrasts with technological determinism, which would be hard-pressed to find a technology that experienced zero failure along its supposed linear trajectory of Progress.

Kuhn's theory is abundantly displayed within the history of CANDU. However, Kuhn believes that paradigm shifts occur within a theoretical vacuum in which real-world circumstances do not affect the adoption or abandonment of paradigms. Two examples of this being untrue emerge from alternative CANDU designs, the Boiling Light Water Reactor (BLW) and the Organic Liquid-Cooled Reactor (OCR). These alternative paradigms were abandoned due to factors outside of their scientific and technological merit. The BLW and OCR models are highly instructive in the study of the technology/Technology divide and the ultimate results of scientific progress/paradigm shifts. Both the BLW and OCR had technical goals unrelated to political or social results, which serves as a rebuttal to post-modern theories of technological advancement leading to technocracy. Additionally, both projects were cancelled during peak efficiency as successes began to outweigh failures. Highlighting the reality of technology's life cycle. Even if a technology is effective or successful and becoming increasingly so, it does not mean it will not be passed over for another, more successful option. Opposing the idea that all technology contributes to Progress and that it is produced with the connotations of Technology.

The BLW design differed from the Pressurized-Heavy-Water Reactors (PHW, the standard CANDU design) as it used light water coolant instead of heavy water (heavy water, D_2O, has deuterium isotopes instead of simple hydrogen-1. A deuterium moderator allows for increased efficiency in nuclear reactions but was prohibitively expensive during the early decades of CANDU). Within BLW, the reaction moderator is still heavy water, which is common and essential to all CANDU designs. Also, the reactor would be fueled vertically instead of horizontally. This orientation change is inconvenient as the entire reactor would need to be shut down to refuel, resulting in periods of intense power output fluctuations from zero output to full capacity. But it costs far less to manufacture due to replacing the heavy water coolant with light water, which has a negligible cost. Additionally, no steam generators would need to be purchased as the light water coolant could act as both the coolant and steam to turn the turbines, generating electrical energy.[115] However, light water captures a much higher rate of neutrons than heavy water. Meaning the reactor would need to burn enriched uranium.[116] Unenriched uranium, U-238, is a naturally occurring element that contains a minuscule amount of the isotope U-235. U-235 is responsible for sustained nuclear reactions but does not occur in high enough natural quantities to sustain most reactor designs. As a result, the process of enrichment was developed in which U-238 was converted to U-235. Enrichment is prohibitively expensive due to facility and equipment costs. CANDU was designed to operate with unenriched uranium as Canada contains most of the world's supply of unenriched uranium and zero facilities capable of enrichment.

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[115] By removing heavy water from the cooling design, the issue of leaks was also removed. A certain amount of coolant water is guaranteed to leak during operation. Light water is nearly free in comparison to heavy water, so the issue of leaks dramatically fell in the BLW design. Hart in Hurst, *Technical History*, 319-320.
[116] Hart in Hurst, *Technical History,* 320.

The different burn-up rates between enriched and unenriched uranium made the BLW reaction difficult to manage compared to existing CANDU designs, requiring more money to produce.[117] Eventually, fuel bundles could be produced at a comparable cost to PHW. However, due to the relatively unstable burn-up rate compared to PHW, the peak power production could only reach 180MWh/kgU while PHW could reach 240MWh/kgU.[118] As a result, the actual cost of fueling a BLW reactor was 25% higher than a PHW reactor. Balanced from the lower operating costs and less capital-intensive light water, the price difference was deemed negligible.[119] Nonetheless, Quebec wanted production experience in the nuclear power sector and licensed a BLW called Gentilly-1, completed in May 1972. The reactor experienced numerous setbacks and issues, such as unreliable fuel burn rates and vertical absorber rod design issues.[120] It shut down in November 1972 to loan its heavy water moderator to Pickering 3 and fix the problems with the fuel burn-up. The issues continued once the reactor was back online in late 1974, resulting in the 1977 decision to cancel the BLW reactor concept. Gentilly-1 was shut down in 1979 and dismantled in 1984.[121] Quebec then commissioned a PHW called Gentilly-2.[122] An important note is that both the UK and Japan successfully operated BLW concept reactors until 1990 and 2003, respectively.[123]

Firstly, the CANDU-BLW failure directly opposes the narrative of Progress. If linear Progress occurred, such as argued by post-modern theorists, then the concept would have eventually overcome its shortcomings and entered into service alongside the PHW due to its

[117] Hart in Hurst, *Technical History,* 320.
[118] Hart in Hurst, *Technical History*, 321.
[119] Hart in Hurst, *Technical History,* 320-321.
[120] Hart in Hurst, *Technical History*, 324.
[121] Hart in Hurst, *Technical History,* 322-324.
[122] Hart in Hurst, *Technical History*, 324.
[123] Hart in Hurst, *Technical History*, 325.

coveted role as a new innovation. Reality does not appear to follow this trajectory. BLW was an unproven technology that diverted a vast amount of capital away from the proven PHW concept. It was then a matter of economics. Gentilly-1 was performing poorly compared to the remainder of the CANDU fleet, and instead of committing more money for uncertain results, the project was cancelled.[124] Simultaneously, AECL was in the process of cancelling the OCR prototype.

AECL approved the OCR project in 1959, to be called WR-1. Like BLW, the pressure tubes were installed vertically. Fuel bundles were strung along a central support beam, unlike PHW, which has fuel bundles inserted as a lattice-type pattern for online refuelling and even burn-up distribution.[125] Similar to the BLW concept, the OCR was attractive because of its low capital costs due to the reduced amount of heavy water needed and the elimination of heavy water leaks. But once again, these savings were offset by higher fueling costs.[126] One significant advantage of the OCR concept was the type of uranium fuel it could use. PHW uses uranium dioxide fuel to avoid corrosion from contact with the heavy water coolant. Without the worry of corrosion (due to no heavy water contact), uranium metal or carbide became available. The fuel would need to be enriched, but these lower-cost, more efficient fuels would partially offset the costs of fuel enrichment and could potentially produce higher total power levels than uranium dioxide.[127]

Unfortunately, there were many problems with the OCR concept. The organic coolant had the issue of decomposing after extended interactions with heat and radiation. The coolant had to

[124] Bothwell, *Nucleus*, 441.
[125] Hart in Hurst, *Technical History*, 325.
[126] Hart in Hurst, *Technical History*, 325-326.
[127] Hart in Hurst, *Technical History*, 325-327.

be precisely controlled because it was flammable.[128] Combustion was later solved. However, AECL was extremely conscious that if it recurred in a full-scale plant, the damage could be severe.[129] This is in comparison to heavy/light water-cooled reactors, where the coolant is inert and requires little oversight. Additionally, the issue of fuel fouling occurred at this time. Fouling was due to the interactions with the uranium metal/carbide fuel and the organic coolant, resulting in organic and inorganic compounds crystallizing on the fuel surface and degrading the fuel. Fouling was eventually overcome due to the production of a new fouling-resistant fuel cladding.[130] Only one fouling incident occurred and provided the needed data for the engineers to produce a new circuit system that allowed WR-1 to operate at 400°C, a more efficient operating temperature than PHW.[131] While this issue was overcome, it would cause worry for AECL managers about the feasibility of the OCR design in the future and influence the final decision to discontinue the reactor.[132] An additional issue with OCR was that organic materials have far poorer heat transfer properties compared to water.[133] Heat transfer capability directly correlates to power output; increased heat transfer capabilities directly correlate to increased reaction efficiency. The coolant outlet and core temperature should operate at similar temperatures for maximum reaction efficiency. For example, in the PHW reactor, the coolant would reach 300°C and the fuel 315°C compared to OCR's 400°C and 500°C.[134] Second, organic coolants are noticeably worse at transferring heat than water and heavy water. This means exponentially more

[128] Hart in Hurst, *Technical History*, 326-327.
[129] Hart in Hurst, *Technical History*, 331.
[130] Hart in Hurst, *Technical History,* 330-331.
[131] Hart in Hurst, *Technical History*, 328.
[132] Hart in Hurst, *Technical History*, 328-329.
[133] Hart in Hurst, *Technical History,* 330.
[134] Hart in Hurst, *Technical History*, 330.

organic coolant is required to cycle through the reactor to remove the same amount of heat as a water-cooled design.[135]

Despite these successes in the lab and WR-1, in 1973, the program was discontinued because PHW was working well. The AECL board of directors saw no reason to produce a competing design.[136] OCR found success in every failure and was on a technical path to success, but it was abruptly cancelled due to budgetary and political reasons.[137] Innovation and invention do not guarantee a technology's use. Additionally, if AECL were intent on producing a technocracy, it would have continued to invest in both BLW and OCR to diversify its control over Canadian power production. Instead, they focused their efforts on the single thing they did well, the PHW. The PHW is one alternative to the multitude of competitive energy production sources. As became clear after the 1980s, CANDU became the product of a bygone era and had little adoption outside of Ontario. To counteract this, AECL should have pursued the BLW in Quebec. Instead, they ensured Gentilly-2 BLW was switched to PHW, and Gentilly-3 was cancelled outright. On the Prairies, they cancelled WR-1, which was being marketed to the three provinces, resulting in zero CANDUs being built west of Lake Huron. AECL continuously executed actions that took them further from a hegemony, not closer to it. While these decisions were made from the top of AECL, an increasingly volatile and antagonistic atmosphere toward nuclear was forming in Ontario, which would have irreversible effects on the trajectory of CANDU.

[135] Hart in Hurst, *Technical History*, 330.
[136] Hart in Hurst, *Technical History,* 332.
[137] Hart in Hurst, *Technical History*, 332.

Chapter Three

Speaking in 1972, W. M. Gilchrist, then President of the Canadian Nuclear Association, stated:

> I don't have to remind you that strong public concern over the operation of nuclear power plants has seriously hampered their construction in other parts of the western world, especially in the United States. We have not experienced this problem to any great extent in Canada, and therefor, I can't help feeling that there is a better awareness of the nature of nuclear energy on the part of both the Canadian public and informed Canadian environmentalists.[138]

Gilchrist was exactly wrong. As will be shown in this chapter, anti-nuclear activism and growing public concern over nuclear energy soon became the defining feature of the industry.

Returning to George Grant, it can be seen that he laid considerable amounts of foundation for modern heuristics and paranoia. *Lament for a Nation* opens with Grant's warning of modern governments willingly or unwittingly working towards a "homogenized culture of the American Empire."[139] For Grant, either option was just as insidious. Grant then asserts that journalists are in the pocket of this ineffectual government. Stating, "The jaded public wants to be amused; journalists have to eat well… The "news" now functions to legitimize power, not to convey

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[138] W. M. Gilchrist, *72-CAN-101: President's Address*, In *Proceedings of the 1972 Annual Canadian Nuclear Association Conference* (Chalk River: Atomic Energy of Canada Limited, 1972), 1.

[139] Grant, *Lament for a Nation*, 7. This theme was common in contemporary Conservative narratives of Canada. For example, see Donald Creighton, *Canada's First Century, 1867-1967* (Toronto: MacMillan of Canada, 1970), which argues the Liberal Party had cut Imperial ties that were being irreparably replaced with even more robust American ones. Creighton's *Canada's First Century* was interestingly also called a Swan Song for Canada, just as Grant's *Lament* had been three years earlier.

information. The politics of personalities helps the legitimizers to divert attention from issues that might upset the status quo."[140] Grant has the foundation of the truth of how media relays information to the public. There are, however, a few issues with Grant's analysis—namely, the role of profits and the ability of journalists to sponsor dissenting opinions rather than state propaganda.

First, he is correct that one of the main functions of mass media is to legitimize those in power. However, the other equally important factor that goes unmentioned by Grant is profits. Grant proposes that the journalists eat well by pandering to the elite and those with power, who then take care of the journalists' needs. This undoubtedly occurs. But the sheer proportion of journalists compared to those in a position to claim the role of patron outweighs the feasibility of this relationship. Where Grant sees a conspiracy that the media has been bought wholesale, the truth is that the majority are out fighting for themselves in a hostile patron-based landscape. Resulting in an arms race of sensationalized coverage. The more outrageous the story, the more it panders to basic human fears and emotions, the more it reinforces biases, and the more likely people are to buy the story and share it with their loved ones or coworkers. This is increasingly how journalists live in the age of mass media. The result is still biased and faulty reporting, just not always in favour of the establishment. This can be seen in the related media of nuclear energy discussed in this paper. Writers prey on people's baser instincts to sow fear and keep them reading, consuming, and coming back for more of the same. This argument is also supported by the literature on heuristics and biases, which form the core of this chapter. Second, while Grant sees the media as a tool to reinforce the status quo, it is just as powerful as a dissenting voice. This is the extension of the previous argument. As misinformation spreads,

[140] Grant, *Lament for a Nation*, 8.

people become disillusioned and further jaded with the status quo. For Canadian nuclear (overseen by government agencies), this resulted in widespread anti-nuclear sentiment after an increasing prevalence of misinformation and well-publicized failures such as Three Mile Island and Chornobyl.

Grant forewarned the public to distrust public and private technological enterprise, which seemed to have come to fruition with the Three Mile Island accident and eventual Chornobyl meltdown. Grant prophetically urged the Canadian public to consider:

> All ruling classes are produced by the societies they are required to rule. In the 1960s, state capitalism organizes a technological North America. The ruling classes are those that control the private governments (that is, the corporations) and those that control the public government [sic] which coordinates the activities of these corporations. North America is the base of the world's most powerful empire to date, and this empire is in competition with other empires.[141]

Grant is sowing the fears that the technological elite are controlling the country and increasingly icing out the average Canadian. Grant later warns the reader that now that political parties (specifically the Liberals) have control of economic policy and planning, they can easily stay in power "almost indefinitely."[142] The excerpts from Grant show the fever pitch of paranoia had infected all facets of Canadian society as *Lament* was a national bestseller. From the lamenting layman to the paranoid philosopher, Technology, technocratic centralized government, and large corporations were major concerns. This manifested itself in the irreparable schism

[141] Grant, *Lament for a Nation*, 9.
[142] Grant, *Lament for a Nation*, 47.

between reputable scientific communication based on quantitative fact and logic and individual qualitative assessments based on heuristics and uneducated feelings.

Grant elucidates a major point about the nature of modern liberal states by saying, "In the private spheres, all kinds of tastes are allowed. Nobody minds very much if we prefer women or dogs or boys, as long as we cause no public inconvenience. But in the public sphere, such pluralism of taste is not permitted. The conquest of human and nonhuman nature becomes the only public value."[143] Grant bemoans this as the "end of ideology."[144] He is correct, but not how he intended. Grant was so focused on dismantling his 'modernist' strawman that he ignored the potential of the post-modernist theory of exploiting 'the end.' As described throughout this paper, technology had been securely co-opted into modern Technology. But this happened parallel to the rise of post-modern liberalism in Canada and the West at large. Grant predicted the progression of liberalism into an isolated individualistic society where the private sphere is untouchable, and the public is sacrificed to the country. Post-modern liberal individuals place their own individual freedoms and comfort above the good of society. However, Grant lamented liberalism would produce a homogenized society of faceless party members when, in reality, it produced a fragmented system of personal freedoms and competition for those personal freedoms. Post-modern citizens are resistant to sacrificing any of their perceived personal freedoms once they have been 'won.' Grant thought his hated liberal modernists would introduce "value judgments," subjective decisions based on choice over judgments of facts.[145] However,

[143] Grant, *Lament for a Nation*, 56.
[144] Grant, *Lament for a Nation*, 56.
[145] Grant, *Lament for a Nation*, 55.

post-modern thinkers universally adopted the value judgment mindset, while modernists resisted it by entrenching themselves further into the judgment of facts.

Value judgments are more widely known by the name 'Affective Heuristics.' Affective heuristics and substitution are a well-known and studied phenomenon in psychology. Affective heuristics is the shortcut that one's emotions produce their reaction to specific stimuli.[146] For example, a nuclear power station produces an effect the individual thinks is negative in their community. Therefore, nuclear power is always negative in their mind. Substitution is the process in which a difficult or taxing decision is replaced with an easier decision that has (in the individual's mind) answered the original question.[147] For example, if someone is asked if they support a nuclear power plant being constructed in their city, instead of considering the benefits and detriments, they substitute the question to 'How will this affect me? It will increase traffic on my commute. Therefore, no.' Essentially, the complex and taxing question is replaced with a personal and subjective question that the immediate offering of an affective heuristic can easily answer. However, substitution is also inextricably linked to the concept of intensity matching. Intensity matching automatically matches the intensity of the substituted question and produces an answer of equal perceived intensity.[148] If someone fears death from a nuclear plant and is asked the previous question, they will match their substituted question as a matter of life or death. These factors come together under affective heuristics with the final component of bias. When executing an affective heuristic, the brain biases whatever is being weighed against the individual's prior emotions on the subject. This means that if one is predisposed to liking or disliking nuclear energy, they will come to a solution that is either biased in favour or against

[146] Daniel Kahneman, *Thinking, Fast and Slow* (New York: Farrar, Straus and Giroux, 2013), 103.
[147] Kahneman, *Thinking, Fast and Slow,* 97.
[148] Kahneman, *Thinking, Fast and Slow*, 99.

nuclear power, respectively.[149] Nuclear power, due to its entangling and conflation with post-modern concepts of Technology, Progress, technocracy, and vast misinformation, has been noted to produce disproportionately negative bias compared to other radiation technologies, such as medical imaging, which has a uniformly positive bias and lacks the external factors applied to nuclear technology.[150]

Affective heuristics, substitution, and intensity matching are often combined in an individual's thought process to produce what hereafter, for simplicity, will be labelled affective heuristics. Affective heuristics are based on an individual's experience with imagery, peer influence, susceptibility to media, base level of effort, and biases.[151] None of these criteria are based on logical reasoning or analysis of factual evidence or theory. Affective heuristics form in the brain so the user can avoid effort in times of overload. What has progressively happened is these shortcuts are being used in everyday life so the individual can avoid strenuous effort or being faced with opinion-altering information. Arguments based on affective heuristics are entirely subjective and are almost impervious to change.

How this manifested in the conversation of nuclear power is the sudden snap of resistance to nuclear power plants being constructed where it could 'infringe' on the private sphere of residents. Citizens resisted the land used by nuclear plants, giving rise to the Not in My/Any

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[149] Ahment Kilinc, Edward Boyes, and Martin Stanisstreet, "Exploring Students' Ideas About Risks and Benefits of Nuclear Power Using Risk Perception Theories." *Journal of Science Education and Technology* 22, no. 3 (2013): 253-254.

[150] Paul Slovic, Baruch Fischoff, Sarah Lichtenstein, "Facts Versus Fears: Understanding Perceived Risk" in Daniel Kahneman, Paul Slovic, and Amos Tversky *Judgment Under Uncertainty: Heuristics and Biases* (Cambridge; New York: Cambridge University Press, 1982), 485.

[151] Maureen Bourassa, Kelton Doraty, Loleen Berdhal, Jana Fried, and Scott Bell. "Support, Opposition, Emotion and Contentious Issue Risk Perception." *The International Journal of Public Sector Management* 29, no. 2 (2016): 204-205.; Kilinc, Boyes, Stanisstreet, "Exploring Students' Ideas," 254.

Backyard movements. They erroneously believed that nuclear energy was guaranteed to be dangerous and thus argued that plants infringed on personal safety. Additionally, people believed, like Grant, that nuclear was another step toward governmental control over the freedom of the population. These resistances grew primarily out of mass misinformation and literacy gaps between the public and the nuclear establishment. These resistances are manifestations of affective heuristics. A series of subjective leaps in judgment that results in a staunch decision to support/oppose a decision with little to no consideration of evidence or facts pertaining to the issue. This pattern has been repeated throughout the history of Canadian nuclear energy and will be detailed in this chapter. What Grant foresaw as the end of ideology was the beginning of a new offshoot as liberalism morphed in the latter half of the twentieth century and combined with post-modern notions of Technology.

Amory Lovins, a prominent American political advisor and anti-nuclear environmentalist, opens his 1979 polemic *Soft Energy Paths* with a suite of arguments. First of importance here is, "We are more endangered by too much energy too soon than by too little too late, for we understand too little the wise use of power."[152] First, Sir Brian Flowers, tasked with heading a British Royal Commission investigation on the safety of nuclear energy, offered direct opposition to this argument despite publishing his report a year prior to Lovins' book in 1978. Flowers stated:

> The human fallibility argument is one that, pressed too far, would set an arbitrary and unduly restrictive limit on technological development. It is imperative that there should continue to be the most rigorous application of safety techniques in the design

[152] Amory B. Lovins, *Soft Energy Paths: Towards a Durable Peace* (New York: Harper Colophon Books, 1979), 12.

> and operation of reactors… the possible effects of conceivable accidents and uncertainties involved in assessing the risks are clearly factors which should be weighed in decisions on nuclear power, as they should be for any other technological development.[153]

Lovins proposes that staying in ignorance is safer than risking moving forward. However, while it is a common argument of post-modern thinkers, this does not work either. An argument Lovins lifted directly from E. F. Schumacher's 1973 *Small is Beautiful: Economics as if People Mattered*.[154]

Lovins' argument is further disputed in the field of risk analysis by scholars such as Aaron Wildavsky. Wildavsky, writing against post-modern conceptions of risk at large, lamented the state of society's "new doctrine: no trials without prior guarantees against error."[155] Highlighting how increasingly dominant post-modern ideas of risk and Technology have infringed upon theories of success through failure and the adoption and proliferation of technology. Wildavsky quotes Robert E. Goodin, a prominent political philosopher during the 1980s, who says:

> Precisely this sort of learning [success through failure] by doing has been shown to be responsible for dramatic improvements in the operating efficiency of nuclear reactors. That finding, however, is as much a cause for concern as for hope. It is shocking that there is any room at all left for learning in an operational nuclear

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[153] Sir Brian Flowers, *Royal Commission on Environmental Pollution: Sixth Report: Nuclear Power and the Environment* (London: Her Majesty's Stationary Office, 1976), 79 - Paragraph 176.
[154] E. F. Schumacher, *Small is Beautiful: Economics as if People Mattered*, (London: Blond and Briggs Ltd., 1973), 146-149.
[155] Aaron Wildavsky, *Trial Without Error: Anticipation vs Resilience as Strategies for Risk Reduction* (Centre for Independent Studies, 1985), 2.

> reactor, given the magnitude of the disaster that might result from ignorance or error in that setting.[156]

Ironically, Goodin has displayed his ignorance of the scientific process during his lamentation of ignorance in science. Fixing points of failure makes a technology safer and more efficient, a point which Goodin acknowledged above and then ignored. They are not warning signs that a technology is becoming increasingly dangerous but safer and increasingly understood. E. F. Schumacher lamented the same issues in *Small is Beautiful*, arguing that supposed scientific ignorance surrounding nuclear energy would outweigh any possible "economic progress" due to its corrosive and corrupting nature.[157]

Risk theorist Cass Sunstein calls this position the "Catastrophic Harm Precautionary Principle."[158] This principle operates by responding to 'worst-case scenarios,' usually with probabilities under 1%, and pursues its complete eradication while, usually, unintentionally producing another hazard that is far worse than the original 1% probability.[159] This thinking laid the foundation for the Precautionary Principle, which argues that even if harm cannot be proven scientifically or quantitatively, it is the responsibility of the producer of the perceived hazard to produce proof of their innocence.[160] Essentially, arguing that if harm is *felt* or *perceived as felt*, those are grounds for cessation of activity and investigation. This theory combines affective heuristics, feelings, and post-modern notions of perceived risks into a theory of opposition to

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[156] Robert E. Goodin in Aaron Wildavsky, *Trial Without Error*, 3.
[157] Schumacher, *Small is Beautiful*, 149.
[158] Cass R. Sunstein, *Worst-Case Scenarios* (Cambridge, Mass: Harvard University Press, 2007), 119.
[159] Sunstein, *Worst-Case Scenarios*, 4.
[160] Sunstein, *Worst-Case Scenarios*, 124.

technological forces. Additional examples of this concerning nuclear energy will be shown below.

A gap in the philosophy of post-modern risk assessment is their insistence on no new technology coupled with zero innovation and no maintenance of 'risky' technologies. With no new pioneers of science and technology, no second generation will follow them, and existing technology will increasingly fall into inefficiency and disrepair.[161] Then, meeting the tenet that 'risky technology' will not be repaired or proliferated due to all risks being unacceptable. This apprehension toward human-made technologies stems from the teaching of Ulrich Beck. Beck is considered one of the most influential scholars of post-modern risk conceptions. Post-modern conceptions of risk utilize Beck's core theory of 'reflexivity' to construct their risk models. Reflexivity argues that risk carries different meanings. "Natural" risks have exponentially decreased while "manufactured" risks have exponentially increased to take their place.[162] Manufactured risks are unevenly distributed across society, while it is argued natural risks are evenly distributed and produce the respective positions of "winners" and "losers" within the distribution of risk.[163]

Beck then expands his theory to include the dimensions of time and space. Meaning manufactured risks have the capacity to affect larger geographic areas and populations at once, and their effects can be delayed, i.e., radiation exposure would not result in mutations until the subsequent generation.[164] Finally, Beck and those sharing similar theories argue that risk

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[161] Wildavsky, *Trial Without Error*, 6.
[162] Gabe Mythen, *Ulrich Beck: A Critical Introduction to the Risk Society* (London: Pluto Press, 2004) 16-17.
[163] Deborah Lupton and Nick Fox. "Postmodern Reflections on 'Risk', 'Hazards', and 'Life Choices." Essay. In *Risk and Sociocultural Theory: New Directions and Perspectives* (New York: Cambridge University Press, 2000), 13-14.
[164] Mythen, *Ulrich Beck*, 18.

operates under "cultural relativism."[165] Cultural relativism argues that risks are only deemed risks when society collectively categorizes them as such.[166] Some argue that risks only exist as a tool of calculation. Meaning risks do not exist until humans calculate them into existence.[167] As a result, risk is now a fluid concept that changes from individual to individual. This change occurred due to the conflation of hazards with guaranteed risk. For example, nuclear plant radiation exposure results from the hazard of an equipment malfunction or operator error. Under the realist risk approach, the solution would be to increasingly refine the equipment to reduce the chance of malfunction and provide specialized training for the operator to further decrease the probability of the hazard occurring. Meanwhile, post-modern theorists argue that the only way forward is to remove the hazard entirely.[168] For example, if one does not build a nuclear plant, zero hazards remain.

Firstly, as a response to this theory, as one's liberal individualism increases, one's self-perception of the importance of one's particular views on risks increases.[169] If every individual's unique risk profile were to be considered, society would encounter such a paralysis that all movement must cease. All technology carries risks, but only some risks are worthy of intensive planning and prevention. The individual makes a multitude of daily "value-laden judgments" to decide if the risks of a certain situation align with their unique risk tolerance.[170] This is the responsibility of independent people with personal agency in the world. They live their lives

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[165] Mythen, *Ulrich Beck*, 97.
[166] Mythen, *Ulrich Beck*, 97.; Lupton, Fox. "Postmodern Reflections," In *Risk and Sociocultural Theory*, 19-20.
[167] Deborah Lupton and Mitchell Dean. "Risk, Calculable and Incalculable," In *Risk and Sociocultural Theory: New Directions and Perspectives* (New York: Cambridge University Press, 2000), 131.
[168] Lupton, Fox. "Postmodern Reflection," In *Risk and Sociocultural Theory*, 16-17.; Wildavsky, *Trial Without Error*, 2.
[169] Deborah Lupton. "Introduction: Risk and Sociocultural Theory," In *Risk and Sociocultural Theory: New Directions and Perspectives* (New York: Cambridge University Press, 2000), 4-5. Interested readers should consider consulting the following monograph Fukuyama, Francis. *Identity: The Demand for Dignity and the Politics of Resentment*. First Picador edition. New York, N.Y: Picador, 2019.
[170] Lupton, Fox. "Postmodern Reflections," In *Risk and Sociocultural Theory*, 17.

according to their own values. Cultural relativists are attempting to impose 'the individual's' values onto society as a new form of governmentality.[171] This harkens back to the phenomenon of the late twentieth century, where governing bodies under governmentality were increasingly being replaced by the individual. It is a complex and odd irony that the progression of post-modern liberalism provided the tools for such an idea so antithetical to classical liberal ideology. Lovins will exemplify this theory below with the continuation of his main arguments from *Soft Energy Paths*.

Secondly, as previously discussed, *all* technology carries risks. Just as nuclear fuel carries radiation, oil wells carry the risk of combustion, and stairs and ramps carry the risk of tripping and breaking bones. Life itself has inherent risks. Embolisms can develop spontaneously, cancers grow at any stage in life, and pneumonia caught on a bitter winter's eve. Post-modern theories of complete inoculation from risk are irreconcilable with living life. The only allowed action within their framework is to lie down and wait for death because only in death are there no remaining risks. Individuals must retain the agency to choose which risks they engage in without policy forcing the ability from them. Catastrophizing any modicum of risk into a reason for ceasing the development of nuclear technology has been a constant feature of the debate and has continuously stifled discussions.[172] Nuclear energy is continually targeted by these actions due to its high level of availability and visibility.

Availability is the psychological process in which a certain piece of information is readily available for recall, requiring little effort or thought to procure.[173] Sunstein cites the increasing

[171] Lupton and Dean. "Calculable and Incalculable," In *Risk and Sociocultural Theory*, 132-133.
[172] Slovic, Fischoff, Lichtenstein, "Facts Versus Fears," In *Judgment Under Uncertainty,* 487.
[173] Sunstein, *Worst-Case Scenarios*, 131.

availability of nuclear energy in a negative light due to Three Mile Island (TMI) (1979) and Chornobyl (1986) happening relatively close together and both being sensationalized in the media.[174] Sunstein's argument is supported by additional scholarship, which found that emotions and perceived risks were inversely related.[175] As emotions skew toward the negative, perceived risks increase.[176] Extremes such as TMI and Chornobyl are additionally relevant because they reinforce the common risk attitudes of the public that, one, risks are "all or nothing," either a catastrophic failure or perfection and two, that manufactured risks are more dangerous than natural risks.[177] Leading to three, people call for a zero-risk policy to avoid thoughts one and two.[178] This argument is supported by the general research on affective heuristics, which argues that to avoid complex and taxing thoughts, people rely on emotionally charged and 'shortcut' thoughts, as shown above. This increasingly shifts the public into post-modern thinking on the concept of risk and technology.

In the name of preference and deference to the opinions and values of the individual, post-modern theory prefers certain opinions and devalues those that oppose them. Post-modern notions of risk also ignore the modern definition of risk. Risk is inherently neutral as it can result in positive or negative outcomes that scale with the intensity and scope of the situation.[179] This insistence on avoiding risks partly stems from a considerable change in definition. The distinction between 'good' and 'bad' risk has been largely lost and replaced with a direct

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[174] Sunstein, *Worst-Case Scenarios*, 131.; Cass R. Sunstein, *Risk and Reason: Safety, Law, and the Environment* (Cambridge, U.K.: Cambridge University Press, 2002), 34.
[175]Melissa L. Finucane, Ali Alhakami, Paul Slovic, and Stephen M. Johnson. "The Affect Heuristic in Judgments of Risks and Benefits," *Journal of Behavioural Decision Making* 13, no. 1 (2000): 2-3.; Paul Slovic, Melissa L. Finucane, Ellen Peters, and Donald G. MacGregor. "Risk as Analysis and Risk as Feelings: Some Thoughts about Affect, Reason, Risk, and Rationality." *Risk Analysis* 24, no. 2 (2004): 314-315.
[176] Finucance *et al*,. "Judgment of Risks and Benefits," 3-4.
[177] Sunstein, *Risk and Reason*, 36.
[178] Sunstein, *Risk and Reason*, 36.
[179] Lupton, *Risk*, 8.; Lupton and Fox, "Postmodern Reflections," In *Risk and Sociocultural Theory*, 17.

connotation. Risk is now directly associated with danger, no matter the context of the situation.[180] The level of danger depends on the individual's familiarity, while some are fixed as unduly dangerous, and others are unduly harmless.[181] Perception of danger increases as familiarity decreases.[182] For example, airplanes have experienced multitudes more accidents than nuclear energy. Yet airplanes are widely accepted and not considered excessively dangerous by society at large. This is due to the level of familiarity air travel commands and the fact it cannot be easily substituted for another technology.[183] Air travel is commonplace and cannot be replaced, so people adjust their sense of danger, or "dread," down to an acceptable level.[184] While nuclear energy is a comparatively scarce technology, few plants exist in Ontario, and all have the option of being replaced with familiar technologies such as fossil fuels or renewables. This substitutability severely hinders the risk perception of nuclear energy.[185] When faced with broad misinformation, perceived dangerousness, high capital costs, negative affective heuristics, and post-modern fears, replacing nuclear with an alternative energy source becomes the default position of the opposition.

By choosing to see risk exclusively as a negative and ignoring the potential gains, one ensures one's own resistance to the concept. Lovins perfectly embodies this theory as he continues his list of arguments within *Soft Energy Paths* by stating, "the technical, economic,

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[180] Lupton, *Risk*, 8.
[181] Mary Douglas and Aaron Wildavsky, *Risk and Culture: An Essay on the Selection of Technical and Environmental Dangers* (Berkeley: University of California Press, 1982), 8.; Kilinc, Boyes and Stanisstreet, "Exploring Students' Ideas," 253.
[182] Kilinc, Boyes, Stanisstreet. "Exploring Students' Ideas," 253.
[183] L. Sjoberg, "Risk Perception, Emotion and Policy: The Case of Nuclear Energy," *European Review (Chichester, England*) 11 no. 1 (2003): 118.
[184] Sjoberg, "Risk Perception," 110, 118.; Annukka Vainio, Riikka Paloniemi, and Vilja Varho. "Weighing the Risks of Nuclear Energy and Climate Change: Trust in Different Information Sources, Perceived Risks, and Willingness to Pay for Alternatives to Nuclear Power." *Risk Analysis* 37, no. 3 (2017): 557.
[185] Sjoberg, "Risk Perception," 120.

and social problems of fission technology are so intractable, and technical efforts to palliate those problems are politically so dangerous, that we should abandon the technology with due deliberate speed."[186] While this position is quite extreme, it is not as extreme as Lovins' self-attested mentor Schumacher, who stated, "To do such a thing [the continued use of nuclear reactors] is a transgression against life itself, a transgression infinitely more serious than any crime ever perpetrated by man. The idea that a civilization could sustain itself on the basis of such a transgression is an ethical, spiritual, and metaphysical monstrosity. It means conducting the economic affairs of man as if people really did not matter at all."[187] Lovins surely learned at Schumacher's foot because this statement alone contains affective heuristics, intensity matching, dogmatic language, catastrophizing, and the post-modern assertion that a state built on Technology is fundamentally flawed.

Schumacher believes nuclear energy is an ethical cancer on humanity's collective soul, while Lovins tones down the language to assert that the issues are complex and, therefore, should be abandoned. In reality, this is precisely when technological progress occurs. A clear display of wishing to abandon any technology with a modicum of risk. To support this claim, he cites Sir Brian Flowers' English Royal Commission report, referenced above, in its entirety. This is technically correct in that Flowers did outline many problems with nuclear energy. Still, it is deeply disingenuous because the conclusions of Flowers' report are diametrically opposed to Lovins's arguments and conclusions. Flowers and his team outlined numerous potential issues with nuclear power, but their ultimate conclusion was that nuclear power was essential moving forward if the issues they raised were adequately addressed.[188] Flowers states directly, "We have

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[186] Lovins, *Soft Energy Paths*, 13.
[187] Schumacher, *Small is Beautiful*, 154.
[188]Flowers, *Royal Commission*, 200-205. Paragraphs 526-535.

considered whether [Britain] should seek to abandon nuclear fission altogether, even if it could be confidently supposed that this could be done without risk of unacceptable restrictions on energy supply in the future, we should not think that such a strategy was wise or justified."[189] Even in a world of perfect conditions for reactor decommissioning, Flowers recommends they continue operating. To imply that Flowers' findings supported the immediate cessation of all nuclear activity is disingenuous and a blatant misrepresentation of the facts.

In reality, what Flowers found is best described as cautious scientific judgment. For example, radioactive fuel from nuclear plants is attacked by Lovins as being an indefensible byproduct of the nuclear industry due to its ability to be cannibalized into nuclear bombs.[190] While Flowers urges caution and perspective by arguing that while, yes, plutonium from a reactor is highly lethal, so are various other chemicals that undergo less stringent safeguard protocols, such as chlorine, which is lethal when 10mg are inhaled compared to the one million tonnes the UK produced in 1976.[191] Flowers' point is one of perspective and protocol. While nuclear material is extremely lethal, yes, it is mined, transported, and used under safety guidelines stringent enough to render it as 'harmless' as chlorine. While neither are truly harmless, they have been contained within these protocols for safe use. This is proper risk management of hazardous material. Technology without risk is once again foundered by perspective. Nuclear fuel can be made into nuclear weapons after an extremely lengthy process, but the materials to make a traditional bomb can be purchased from most big box stores without suspicion. Within Lovins' home country of America, rifles and handguns are available for retail

[189]Flowers, *Royal Commission*, 193. Paragraph 508.
[190]Lovins, *Soft Energy Paths*, 178-183.
[191]Flowers, *Royal Commission*, 73. Paragraph 162.

purchase. Those technologies, objectively, carry far more explicit user intent and capacity for risk than the scenario of nuclear material being stolen and turned into a homemade bomb.

Both Lovins and Goodin argued above that the effects of nuclear cannot be calculated/accounted for and, therefore, are too risky to pursue.[192] This argument does not account for the insurance industry, whose entire mandate is to calculate and assign risk probabilities to various outcomes. The severity of the hazard cannot be calculated, such as the emotional impact of having a limb amputated, but what is calculated is the probability of this hazard coming to fruition, risk.[193] Risk has been accepted globally as a form of sociopolitical assurance that if a risk transpires, one is entitled to a predetermined form of compensation. Allowing the individual to conduct themselves as they see fit alongside the risks of daily life.[194] As insurance has been accepted within all power industries, including nuclear, it stands to reason that the risks *have* been calculated and accepted accordingly by the end user. Nuclear energy is not an "intractable" form of risk, as Lovins puts it, but a standard calculation in the modern world.[195] The issue of insurance underlies the broader issue of faulty or misunderstood calculations and data that are endemic within the anti-nuclear school.

The 'plutonium myth,' briefly alluded to by Flowers, is the idea that plutonium (a byproduct of nuclear energy reactions and naturally occurring element) is the single deadliest substance on earth and, as such, should be avoided at all costs. The plutonium myth is located at an intersection of 'bad science,' 'bad data,' and insincere motivations. Nuclear realist historian Gordon Sims took issue with this plutonium myth being disseminated throughout Canada. Sims

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[192] Lovins, *Soft Energy Paths*, 13; Wildavsky, *Trial Without Error*, 3.
[193] Lupton and Dean, "Calculable and Incalculable." In *Risk and Sociocultural Theory*, 138.
[194] Lupton and Dean, "Calculable and Incalculable." In *Risk and Sociocultural Theory*, 139.
[195] Lovins, *Soft Energy Paths*, 13.

traced the origin of the myth to American physicist Dr. Donald Geesaman's 'hot particle theory.' Geesaman calculated that a particle of plutonium with a diameter so infinitesimally small to contain only 0.23 picocuries (a picocurie is one trillionth of a curie) of radiation would be enough to develop fatal lung cancer with absolute certainty.[196] A particle of this size would weigh 4×10^{-12} grams, so a single gram of plutonium could kill up to 3×10^{11} people.[197] Or enough to kill the world population multiple times over. Sims argues that Geesaman's theory does not stand to scrutiny.

Firstly, Geesaman's theory relies on the scenario in which the particle entering the lungs stays fixed in place and does not travel across the lung membrane as particles entering the lungs are known to do. As the particle moves throughout the lungs, the 4×10^{-12} gram particle now has to irradiate the entire lung, which weighs on average one kilogram as opposed to a single hot spot of a few micrograms.[198] For lung cancer to be guaranteed, the particle size would need to be exponentially larger. Second, Geesaman calculated his particle size under the assumption that zero plutonium already existed in the air. The United States alone spread over three tonnes (three million grams) of plutonium into the atmosphere during their nuclear weapon testing of the 1950s and 60s. Which, under Geesaman's theory, should have killed the contemporary world population "one hundred million times over."[199] Third, New York State residents inhaled an average of 43 picocuries from radioactive fallout between 1954 and 1975, but their rates of fatal lung cancer remained normal.[200] Finally, Sims tracked a group of plutonium miners from the

[196] Sims, *The Anti-Nuclear Game*, 59.
[197] Sims, *The Anti-Nuclear Game*, 59.
[198] Sims, *The Anti-Nuclear Game*, 59.
[199] Sims, *The Anti-Nuclear Game*, 59.
[200] Sims, *The Anti-Nuclear Game*, 59.

Second World War who inhaled between 6,000-80,000 picocuries during their careers and found their rates of fatal lung cancer to be normal.[201]

Data has an implicit trust attached to it. An expert seems to have gathered vast amounts of data, run rigorous calculations, and then presented their findings to the public, which has an air of trust. Western populations have a higher average level of trust in non-establishment researchers and their associated groups to obtain their nuclear information.[202] At the same time, pro-nuclear organizations and governments were seen to have a uniformly negative connotation with public trust.[203] It is highly likely these feelings would intensify when combined with the fears of technocratic and increasingly centralized organizations and governments. Academics who use this trust to further agendas, such as factually incorrect and ideologically motivated data statements, are abusing this trust and sacrificing their academic integrity for social results. This issue is alarming when combined with the public's vast inability to perceive false information and understand scientific developments. This is a prominent issue, which is featured below when combined with further examples of nuclear misinformation.

Theorists such as Lovins and Goodin grasp onto technologies such as nuclear and catastrophize the 'what if?' scenarios but ignore the 'now' of reality. This is an essential issue with post-modern theorizing of risk, Technology, and Progress. They tend to overlook the contexts of reality before them in favour of increasingly metaphysical arguments. Lovins continues to serve as a case study in these post-modern ideas of Technology. Stating:

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[201] Sims, *The Anti-Nuclear Game*, 60.
[202] Vainio, Paloniemi, and Varho, "Weighing the Risks," 562.
[203] Vainio, Paloniemi, and Varho, "Weighing the Risks," 563-564.

> Ordinary people are qualified and responsible to make these and other energy choices through the democratic political process, and on the social and ethical issues central to such choices the opinion of any technical expert is entitled to no special weight; for although humanity and human institutions are not perfectable [sic], legitimacy and the nearest we can get to wisdom both flow, as Jefferson believed, from the people, whereas pragmatic Hamiltonian concepts of central governance by a cynical elite are unworthy of the people, increase the likelihood and consequences of major errors, and are ultimately tyrannical.[204]

This argument becomes seriously weakened under scrutiny. One, the invocation of Jefferson is in bad faith when applied to issues of technology. For example, advanced technology in Jefferson's time was the musket. No technical expertise is required to grasp the concepts. Any layperson could be trained in a musket's production, maintenance, and use. This contrasts the modern day when the public needs to grasp biotechnology, computers, nuclear energy, and vaccines while they are undereducated, untrained, and largely ignorant of their properties due to less-than-perfect educational support.[205] The contexts of the two eras are alien to one another. What would constitute expert knowledge during Jefferson's time would not advance beyond the high school level in modern society. Giving rise to the modern deficit model thesis, which states that modern individuals without STEM knowledge or expertise are ill-equipped to function as informed voters in the public sociopolitical sphere.[206] Two, Lovins invokes the spectre of Grant, Foucault, and post-modern theorists of an incoming tyrannical technocratic government by emphasizing

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[204] Lovins, *Soft Energy Paths*, 14.
[205] Shawn R. Robinson, "The Influence of Knowledge Acquisition on Attitudes Towards Radiation and Nuclear Technologies Among Non-Experts in Saskatchewan." (Master of Public Policy Thesis, University of Regina, 2020), 3-7.
[206] Robinson, "The Influence of Knowledge," 4-5.

the role of the individual within the democratic process directly opposed to the tyrannical Hamilton. This line of thinking has been dismissed above due to nuclear energy's pointed disinterest in political dominance.

Third, centralized governments do not equal tyranny by default. All socialized states are centralized (for example, Canada's healthcare), but no credible thinker would accuse the Canadian state of vast technocratic tyranny via the healthcare system. The system can be profoundly ineffectual and unevenly distributed across the country, yes, but a tyranny, no. Fourth, the idea that centralized government is "unworthy" of the people is one of the hyperinflated post-modern liberal ideas of individuality.[207] Writers within this ilk, like Lovins, assert the system is broken because every individual does not get to table their ideas (no matter how ill-informed or ill-conceived) when they could perhaps be remotely affected. This way of thinking disregards the structure of classic liberal government systems. Within classical liberalism, every individual has their own opinions and beliefs; they then nominate a representative who they believe most closely aligns with these beliefs, and the representative makes policy decisions. In the proposed post-modern liberal system, every individual would have their opinions heard and considered. This is simply impossible for running an effective government. Communications would overload and shut down. The state would be paralyzed under the weight of opinions *ad infinitum.* As will be seen throughout this chapter, post-modern theories are antithetical to a logical, scientific, and effectual liberal system of beliefs.

[207] As mentioned above, the following work deals with these issues in full. Fukuyama, Francis. *Identity: The Demand for Dignity and the Politics of Resentment*. First Picador edition. New York, N.Y: Picador, 2019.

Ironically, if post-modern theories of risk and Technology were implemented, the world would become increasingly centralized instead of decentralized. Within post-modern risk societies, every single risk must be accounted for before the technology ever reaches the market due to a single risk being unacceptable. Only institutions with enough capital, labour, and time horizons to sustain near-indefinite development cycles would be able to produce or innovate any form of commodity. The only institutions with these qualities are mega-corporations and governments.[208] All smaller competitors would be erased due to attrition of resources. Therefore, the post-modern practices implemented to avoid a technocratic society would assuredly produce that very society.

The first and fourth rebuttals above are the most important for a crucial reason: the mass inability to navigate modern life among Canadians. Mass inability is not unique to Canada, but within the context of the Canadian nuclear power debate, it is of the highest importance. Within the International Adult Literacy and Skills Survey (IALSS) conducted by Human Resources and Development Canada in 2005, illiteracy was found to be endemic throughout the country in all age categories. Within IALSS, illiterate versus literate does not mean literally the ability to read/complete simple math/function at a base level. The study examined the citizens' ability to move beyond the basic definition of literate/illiterate. For example, the IALSS found that nine million Canadians aged 16-65 were functionally illiterate at reading prose (rising to twelve million when the age range expands above 65.)[209] Items under general prose literacy include newspaper articles, journals, brochures, instruction manuals, and books, all for the general

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[208] Wildavsky, *Trial Without Error*, 6-7.
[209] Human Resources and Skills Development Canada, Lynn Barr-Telford, et al., “Building on our competencies: Canadian results of the International Adult Literacy and Skills Survey,” (2005), 7.

reader.[210] This does not mean that twelve million Canadians cannot read. It means they cannot read *well*.[211] Common results are misinterpreting authors' meaning and message, not finishing whole works, and skimming but feeling confident that they have properly read the piece. Norris and Phillips documented this phenomenon with startling results. They presented Albertans with a popular science newspaper article that presented a self-attested, unconfirmed hypothesis about the moon Europa. Once they had read the article, Norris and Phillips asked if the hypothesis was true, untrue, or unconfirmed. 19% correctly said it was unconfirmed, while 25% said it was true, and 52% said it was likely true.[212] This startling example shows the intersection of lacking prose skills combined with self-assured confidence made possible by the post-modern liberal state that prizes individuals' abilities to make sound judgments. Within the context of nuclear energy, these would be the people reading the technical publications from nuclear organizations, news articles written on the topic, and all written material explaining how nuclear power works. How can Lovins' Jeffersonian ideal function when applied to nuclear energy when the public, at large, misconstrue standard scientific and literary prose?

Numeracy literacy and problem-solving literacy were also included within the IALSS. The former is the comprehension of complex numbers and basic statistics, and the latter is the ability to reason oneself through a novel situation without relying on affective heuristics or routines from an unrelated situation.[213] Numeracy illiteracy amounted to 55% across Canada and

[210] Barr-Telford, *et al*., "Building our Competencies," 13.
[211] This issue is by no means isolated temporally or geographically to Canada. Hannah Arendt published her notorious essay, *The Crisis in Education*, in 1954, and it had been widely translated into English by 1963. Arendt critiques the North American education system's systemic failings to produce high-quality graduates due to an inadequate overarching system.
[212] Stephen P. Norris and Linda M. Phillips, "How Literacy in its Fundamental Sense is Central to Scientific Literacy." *Science Education* 87, no. 2 (2003): 234.
[213] Barr-Telford, *et al*., "Building our Competencies," 13.

between 53-59.6% in Ontario.[214] Little change was found between the 1994 and 2005 surveys.[215] Norris and Phillips found similar complaints about the Baby Boomer generation upon their entering into university (circa 1988.)[216] It is probable to suggest these issues have always been present in modern society and did not suddenly manifest during the end of the century. Indicating that they most likely contributed fundamental context of the nuclear energy debate.

A crucial caveat to these statistics is that the IALSS system was tiered. Level One is the inability to function in the category, and Level Five is knowledge equivalent to graduate-level education.[217] Level Three was the standard. Between 25-27% of Ontarians scored a Level One in numeracy skills, meaning they are unable to complete accurate mental math or complete one-step operations.[218] Unrelated research in psychology has found that among educated lay people, numbers within and beyond the range of 1/1,000 to 1/1,000,000 lose all meaning.[219] These ramifications for the nuclear debate are worth noting. Recall the 'plutonium myth' above. The numbers of Geesaman are of orders of magnitude that are rarely seen outside of scientific research. Given the potentially precarious position of numeracy skills in Canada, these orders of magnitude could instill a worsening sense of fear. Fear from seeing such gargantuan lethal capacity attached to a number so microscopic. If the reader is not well versed enough in chemistry, mathematics, and biology to know that these numbers and biological results are almost certainly unattainable in the real world, affective heuristics would almost surely engage.

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214 Barr-Telford, *et al*., "Building our Competencies," 26-27.
215 Barr-Telford, *et al*., "Building our Competencies," 9, 15, 33.
216 Norris and Phillips, "Literacy in its Fundamental Sense," 227.
217 Barr-Telford, *et al*., "Building our Competencies," 14, 28.
218 Barr-Telford, *et al*., "Building our Competencies," 28.
219 Slovic, Fischoff, Lichtenstein, "Facts Versus Fears," In *Judgement Under Uncertainty*, 486-487.

All forms of affective heuristics would engage upon this point. Negative emotions associated with death are now tied to plutonium and, by extension, nuclear energy. Intensity matching would catastrophize the risk of nuclear energy to one of global destruction, and the issue of death would substitute for plutonium usage. The web of affective heuristics involved in lay thinking about nuclear energy is demandingly complex to parse out due to decades of post-modern influence on public perceptions and consciousness. Writers such as Grant seeded the public mind with a Canadian state bent on technocracy. Growing support of Progress with Technology as the defining characteristic was conflated with literal technology and eventually overrode the original definition. Also, due to Group Polarization, as these groups began to form their opinions would gradually lean toward extremes.[220] A public disinterested in learning about science and the lack of universal possession of tools to learn would entrench themselves further into their preformed opinions. Post-modern conceptions of risk are increasingly dominating the conversation and crowding out quantitative approaches. Finally, if a quantitative discussion does occur, most people lack the ability to abstract themselves rationally to comprehend the numbers being discussed, so affective heuristics are engaged as a failsafe to avoid strenuous thinking.[221] These factors all coalesce to produce a society that was fundamentally hostile to nuclear energy proliferation and manifested itself fully in Ontario.

Common points of contention within the nuclear debate were if the energy was really needed, that radiation was unacceptably deadly, and that plant safety was too unpredictable. First, if energy was needed. As mentioned above, energy consumption in Ontario was expected

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[220] Cass R. Sunstein, *Going To Extremes: How Like Minds Unite and Divide* (Oxford: Oxford University Press, 2009), 2-3.
[221] Slovic, Fischoff, Lichtenstein, "Facts Versus Fears," In *Judgement Under* Uncertainty, 464.

to grow at an average of 4% per year from 1977-2000.[222] This potential near doubling meant that new forms of power were essential to meeting consumer demands. Nuclear energy was the safest and most cost-effective choice $/MWe produced at the time, and costs continued to fall due to compounding research.[223] The talking point for anti-nuclear individuals was the exorbitant upfront costs of a nuclear reactor. For example, the original estimate for NPD and Douglas Point was $140 million in 1959.[224] Combined with the issue of heavy water leaks within early CANDU reactors, racking up exponential costs. These leaks could range from 4kg/h to 20kg/h at the contemporary price of $60/kg.[225] However, the price of heavy water fluctuated regularly. For example, by 1964, it had been reduced to $45/kg.[226] An additional factor is that leaked heavy water could be recovered and 'upgraded' back to operational purity levels for a reduced price.[227] These leaks would eventually be sealed, and heavy water escape would be reduced to a negligible amount across all CANDU plants. This was a severe concern in the early years of production. However, the coal and oil that nuclear replaced would easily offset the intensive upfront capital.

In 1959, it was estimated that if the proposed nuclear plants were approved (at the time, NPD and DPGS), they could eventually replace 300 million tonnes/year of international coal imports.[228] This eventually manifested in $335 million saved on coal imports by 1977 and was

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[222] *CA2ON-Z1-756002 Race Against Time*, Presented to Rene Brunelle, XI.
[223] Smith, *AECL-4357*, 20.
[224] Bothwell, *Nucleus*, 242-243.
[225] Woodhead *et* al., *AECL-3972*, 8-10.
[226] Woodhead and Brown, *Performance and Problems of NPD*, 315.
[227] Leaked heavy water ranged from purity downgrades from 99%-10%. To restore operating purity at 99% would cost $1/kg, 90% $3.4/kg, 70% $5.0/kg down to 10% $27.00/kg. Woodhead and Brown, *Performance and Problems of NPD*, 315.
[228] Bothwell, *Nucleus*, 242.

expected to grow to $1.5 billion by 1988.[229] How are these projected amounts saved supposed to influence a public that had potential difficulties with base numerical skills? These numbers are beyond basic understanding and require developed abstraction to appreciate in their entirety. Additionally, holding two competing rates in one's head ($/MWh if coal is pursued or $/MWh if nuclear is chosen) in addition to price comparisons of purchasing hundreds of millions of tonnes per year of coal versus hundreds of kilograms of uranium and thousands of kilograms of heavy water. This information would then need to be compared to growing energy needs, and the individual would need to decide where their opinion rested upon considering all the data. These findings were presented in technical publications from AECL and presented at international conferences. The opportunity to read and experience them existed for the public. But how much good could access to them have done if the education system had not given them the tools to appreciate the nuance and findings? This ability was underdeveloped in swathes of the public and almost assuredly impacted the reach of factual nuclear economic information. It could potentially be too stringent to expect the public to consider all these factors when deciding to support nuclear energy, fossil fuels, or alternative energy sources. Especially considering affective heuristics drives most decision-making in the nuclear debate.

Second, the point of radiation lethality. Radiation lethality was a familiar cudgel used by anti-nuclear pundits to render debate impossible. The rejoinder of an unsafe and potentially lethal technology within a community renders all debate impossible, as it would trigger the intensity matching heuristic. Rendering the conversation one of preservation of life and not nuclear advantages and disadvantages. Dr. Arthur Porter used this tactic during the Ontario Royal Power

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[229] Leonard & Partners Ltd., *Economic Impact of Nuclear Industry in Canada*, (Ontario: Canadian Nuclear Association, 1978), II-8.

Commission on Electric Power (1975-1981). Porter argued that the only reason radiation was deemed safe by the nuclear establishment was because radiation lacked enough time to be properly studied.[230] This argument is false and ignores clear evidence from the nuclear industry. It also ignored propaganda from other anti-nuclear activists, such as Schumacher. Schumacher argued the exact opposite in *Small is Beautiful*, arguing it was perfectly understood and compared ionising radiation to "bullets tearing into an organism."[231] Schumacher's blatant fear-mongering with the comparison to bullets aside, how can radiation be both understudied in 1977 (Porter) but "perfectly well known" (Schumacher) in 1973?[232] A common theme seen above and below is that the anti-nuclear establishment was constantly at odds with itself and often could not agree on which form of propaganda to use, so they utilized multiple, often contradictory, forms. Dr. Rosalie Bertell, a Canadian-American anti-nuclear researcher and activist, was a familiar figurehead during the radiation fervour of the late 70s to early 80s with the publishing of her *Handbook for Estimating Health Effects from Exposure to Ionising Radiation* (1984; 2nd ed., 1986).

Bertell's *Handbook* became the default talking point for data-driven arguments against radiation. This text was of a low academic quality and riddled with errors and fallacies. In 1986, Bertell herself, when examined in court over a British nuclear reactor, admitted the research was faulty on the grounds of selection bias in the data, exclusively used the largest incident rate of cancer due to radiation, misquoting data, conflated lethal and non-lethal cancers within the data,

[230] Pollution Probe - Ottawa, *CA2ONRC75E6419: More than the Price is Wrong: A Case Against Nuclear Energy*, Presented to Arthur Porter as Chair of the Royal Commission on Electrical Power Planning (Ottawa: 1977), 3.
[231] Schumacher, *Small is Beautiful*, 144.
[232] Schumacher, *Small is Beautiful*, 144.

falsely multiplying her fatality numbers to achieve a result 35 times larger than reality.[233] The governing scientific bodies of Canada did not accredit Bertell's research due to these errors. Bertell accused these bodies of bias and lack of expertise within their boards, citing ten experts missing from the ranks of the ICRP (International Commission on Radiological Protection.)[234] This critique is misleading and factually wrong. Seven of the ten 'missing' experts had and continued to work for the ICRP.[235] The reason Bertell's research was never accredited was due to the litany of errors within it. Not due to a lack of experts within the ranks of the governing bodies. Academic disrepute did not affect Bertell's reach as she and Dr. Carl Johnson, an American anti-nuclear radiation researcher with overlapping views and academic practices as Bertell, were the scientific experts interviewed on CBC's *The Journal* shortly after the 1986 Chornobyl accident. Despite Bertell and Johnson being a minority among scientists and not accredited by any governing scientific body, they were chosen as the expert scientific witnesses by Canada's most prominent news corporation.

This decision displays numerous issues discussed within this paper. First is Grant's cynical assertion that journalists must eat, so they choose inflammatory people and opinions that drive metrics up. 'Fear sells' is a well-known phenomenon, and with Bertell and Johnson being their country's respective alarmists, fear was almost surely provided. Second, Bertell was known to rely on qualitative stories of death and suffering, especially of children, to support her arguments rather than overt data.[236] This qualitative and highly effective tactic would

[233] Sims, *The Anti-Nuclear Game*, 65. Sims quotes the findings of Sir Frank Layfield. The lawyer presiding over Bertell's questioning. Layfield's findings are archived in the UK National Archives under the section heading Sizewell B Inquiry.
[234] Sims, *The Anti-Nuclear Game*, 65-66.
[235] Sims, *The Anti-Nuclear Game*, 66-67.
[236] Rosalie Bertell, *No Immediate Danger: Prognosis for a Radioactive Earth* (Toronto: The Women's Press, 1985), 1.

immediately trigger affective heuristics within viewers. Nuclear energy is linked to dangerous radiation, and dangerous radiation is linked with the painful deaths of children. As Bertell self-admittedly relied on faulty data, she removed coherent discussion of data from the conversation entirely. Focusing on arguments that have no equivalent in science. No amount of rational data or assurances of safety can override the intense fear of death or "gut reactions."[237]

Despite the faulty quantitative data, radiation alarmist arguments do utilize the tactic of data-driven arguments. Bertell argues that nuclear weapon testing and nuclear power plant operations to the year 1976 blanketed the population of the northern hemisphere with 300-450 mrem of radiation and 150-300 mrem in the southern hemisphere.[238] Without context, these numbers give cause to pause. First, it is improbable that a blanket dose settled on the northern and southern hemispheres. Due to a multitude of factors, such as wind patterns, humidity, and localized rogue weather systems, a uniform dose is almost assuredly unlikely to have fallen across entire continents.[239] How high is this proposed dose? It is comparable to a single year of average daily life radiation exposure. For example, North America's average radiation absorbed from the sun, earth, surroundings, and all other sources amounts to approximately 310 mrem/year.[240] Living at a high elevation, such as Colorado, could increase the yearly exposure by 60-100 mrem, while living in parts of the world with soil rich in radioactive material, such as India, can increase the annual dose to 600-1000 mrem.[241] Global health officials do not advise all

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[237] Sjoberg, "Risk Perception," 110.
[238] Bertell, *No Immediate Danger*, 56-57.
[239] See the work *A Path Where No Man Thought: Nuclear Winter and the End of the Arms Race* (Random House: New York), 1990. While the work is deeply flawed in its assumptions and assertions of the effects of nuclear energy on the environment, it does have detailed sections and calculations pertaining to how radiation/radioactive fallout would have spread globally following the nuclear tests cited by Bertell.
[240] Sims, *The Anti-Nuclear Game*, 41.
[241] Sims, *The Anti-Nuclear Game*, 42.

residents of India to abandon the country due to increased background radiation exposure. Similarly, North Americans have no cause to worry about lingering radiation from nuclear technologies. Most importantly, the average mrem/year absorbed by the public living around Canadian nuclear reactor sites is nearly that of a television set at an effective dose of <1 mrem/year.[242]

AECL conducted numerous radiation screenings and data collections since its inception. The first report of relevance is *AECL-9344 Mortality Among Long-Term Chalk River Employees*, which was conducted in 1986 and includes data back to Chalk River's inception in 1944. The following 'expected' data values are the averages calculated from the general Canadian and Ontario populations. The report found that between 1944 and 1966, both cancer and cardiovascular death rates were typical, with 22 (22.19 expected) and 72 (79.73 expected) respective deaths in total during the period.[243] This trend continued between 1967 and 1985, with 119 cancer deaths (127.7 expected) and 237 cardiovascular disease deaths (262.7 expected.)[244] Additionally, both rates of lung cancer and lymphatic cancer were lower than expected among Chalk River employees from 1944 to 1986. 40 lung cancer deaths (42.3 expected) and 8 lymphatic cancer deaths (11.2 expected.)[245] These results all fall within the standard deviation of national statistics and do not point to a confirmable decrease or increase in cancer/disease caused by radiation among the staff. However, it does support the conclusion that they did not experience cancer rates outside of the norm. Relevant to this discussion is the decontamination of NRU that took place in 1958. AN NRU fuel rod caught fire and contaminated the reactor core

[242] Sims, *The Anti-Nuclear Game*, 41.
[243] M. M. Werner and D. K. Meyers, *AECL-9344: Mortality Among Long-Term Chalk River Employees* (Chalk River: Atomic Energy of Canada Limited, 1986), 2.
[244] Werner and Meyers, *AECL-9344*, 3.
[245] Werner and Meyers, *AECL-9344*, 4.

room, requiring a clean-up effort of a few months. The clean-up crew members were monitored from 1958 to 1982, and their cancer rates were found to be comparable to both the NRX clean-up crew statistics and the national and provincial averages. Of the 537 AECL staff members involved, 24 died from cancer, compared to an expected 22.5.[246] Of the 194 staff members who participated in both clean-up operations, 7 cancer deaths emerged out of an expected 8.8.[247] Once again, this falls within the standard deviation, indicating neither a decrease nor an increase in rates of cancer among staff. These steady results place Chalk River employees as marginally below average to exactly average in rates of disease stemming from radioactive exposure, providing a compelling data-driven argument against the arguments of nuclear energy producing cancers/disease at higher rates.

Of further importance is that radiation is not a unique hazard. While radiation is exceptionally deadly in large doses, yes, it is primarily feared as carcinogenic and mutagenic. Carcinogenic and mutagenic compounds are not uncommon in daily life. Ranging from wood fires to oil furnaces, fluidized-bed coal burners, and gasoline engines.[248] When the chairman of the Ontario branch of the Canadian Coalition for Nuclear Responsibility was asked if these carcinogenic and mutagenic substances were as well studied as radiation, he replied he did not know.[249] The biological consequences of radiation are amongst the most studied aspects of

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[246] M. M. Werner, D. K. Meyers, and D. P. Morrison, *AECL-7901: Follow-Up of AECL Employees Involved in the Decontamination of NRU in 1958* (Chalk River: Atomic Energy of Canada Limited: 1982), 6.
[247] Werner, Meyers, and Morrison, *AECL-7901*, 9.
[248] J. A. L. Robertson, *AECL-6200: Final Argument Relating to the Canadian Nuclear Power Program* (Chalk River, Atomic Energy of Canada Limited, 1978), 15.
[249] Robertson, *AECL-6200*, 15.

nuclear energy production and, as a result, have the most stringent security safeguards in the power industry.[250]

Returning to Bertell for a final time, she has been caught resorting to outright lies to smear the reputation of nuclear reactor safety. The specific bad faith began in her 1985 book *No Immediate Danger*, with the title of the chapter in question called "The Cover Ups."[251] In the chapter (purportedly on nuclear reactor safety and conspiracy theories), Bertell disingenuously and unfairly primes her reader by opening a chapter on nuclear reactor safety with a graphic account of the American atomic bombing of Japan.[252] Now that the reader is primed with intensity matching and heightened negative emotions toward nuclear science in general, she begins outlining various bad faith and false theories of nuclear establishment conspiracies. Specific to Canada, she outlines numerous false statements about the "December 13, 1950" (actually December 12, 1952) NRX accident at Chalk River.[253] Bertell states, "A hydrogen explosion occurred, killing one man and seriously contaminating five others. The reactor core was largely destroyed [sic] and 1 million gallons of highly radioactive water flooded the structure."[254] Every aspect of the first sentence is wrong, and the second is misleading. First, the NRX accident was not the result of an explosion—nuclear reactors 'meltdown,' hence the common phrase. Due to a failure in the shutdown systems, the reactor exponentially increased in power, which resulted in the melting of the uranium fuel, damaging the reactor.[255] It is

[250] G. C. Laurence, *CA2ONRC75E6330: Nuclear Power Station Safety in Canada*, Presented at the Meeting of the Niagara-Finger Lakes Section of A.N.S., (January 1972), 1-11.; The referenced statement is the thesis of Gordon Sims, *A History of the Atomic Energy Control Board* (Quebec: Minister of Supply and Services Canada, 1981).
[251] Bertell, *No Immediate Danger*, 135.
[252] Bertell, *No Immediate Danger*, 135-139.
[253] Bertell, *No Immediate Danger*, 170.
[254] Bertell, *No Immediate Danger*, 170.
[255] W. B. Lewis, *AECL-232: The Accident to the NRX Reactor on December 12, 1952. (Part I.)* (Chalk River: Atomic Energy of Canada Limited, 1953), 1.

impossible for a nuclear reactor core to explode because it lacks the numerous components, most of all a trigger, to produce an explosion. A nuclear reactor cannot accidentally become a nuclear bomb and vice versa. However, this erroneous claim reached as far as *Man's Magazine* based in Idaho, which asserted the "… thunderous explosion flung scores of some 1,800 workers to the ground."[256] This is a startling example of how far false information can spread and stay in vogue despite mounting evidence of its lack of truth. The *Man's Magazine* article predated Bertell by over twenty years, with Henry B. Piper's sourcing of the 1961 article. It seems that once a suitably inflammatory assertion peaks affective heuristics in the population, it will be challenging to stamp out.

Second, zero fatalities occurred, and after decades of monitoring, zero cancer deaths could be attributed to the accident and subsequent cleanup.[257] Using 1969 data, AECL calculated a 6×10^{-4} chance of dying in a general accident, while dying from a nuclear accident was 2×10^{-10}.[258] With the chance of general injury being 3×10^{-4} for the extremely risk-averse and the chance of injury from a nuclear accident being 1×10^{-8}.[259] Essentially, with rates of potential death and injury multiple orders of magnitude apart, nuclear energy is by far one of the safest technologies the individual could interact with. Thirdly, no staff were notably contaminated.[260] Fourthly, the moderator water was 'dumped' into the basement on purpose to cease the reaction,

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[256] Henry B. Piper, "ORNL-NSIC-100. Fact and Fiction Concerning Nuclear Power Safety" in *Nuclear Power and Radiation Perspective Selections from Nuclear Safety. (*U.S. Department of Commerce: National Technical Information Service, March 1974), 31.

[257] M. M. Werner, D. K. Meyers, and D. P. Morrison, *AECL-7760: Follow-Up of CRNL Employees Involved in the NRX Reactor Clean-Up*, (Chalk River, Atomic Energy of Canada Limited, 1982), 7. Anecdotally, the clean-up crew lived one year beyond the norm on average. Werner, Meyers, and Morrison, *AECL*-7760, 9.

[258] K. R. Weaver, *et* al., *AECL-5800: Nuclear Power: The Canadian Issues. Submission to the Royal Commission on Electric Power Planning* (Chalk River: Atomic Energy of Canada Limited, 1975), 14.

[259] Weaver, *et* al., *AECL-5800*, 14.

[260] Lewis, *AECL-232*, 1, 1-10.; Werner, Meyers, and Morrison, *AECL-7760*, 6-7.

not as a result of an explosion, as is implied within Bertell.[261] This was a built-in safety feature of CANDU reactors. Without moderator water, the reaction ceases within a few seconds. The NRX crew purposefully dumped the water into the basement, where it would not affect any staff. The water was highly irradiated and caused damage to numerous systems within the basement level.[262] However, the safety protocols were immediately executed, and the water was drained, the area decontaminated, and the systems repaired with damages exponentially lower than if the moderator had not been dumped.[263]

The NRX accident was an invaluable learning experience for future CANDU designs. NRX had over 900 shutdown systems in the interest of making everything as optimal as possible. In reality, this complex cascade of hundreds of systems hindered the abilities of NRX staff to contain the accident and could have easily made the situation worse by overloading the operator with such a tangled order of operations that they were more likely to make avoidable mistakes.[264] In 1972, G. C. Laurance, head of reactor safety, cited this issue within NRX as the inciting incident for an overhaul of CANDU safety design.[265] Laurence would formulate an analogy from the NRX experience that governed CANDU design, in general, moving forward, saying, “One of our criticisms of the original safety precautions in the NRX reactor was that there was far too much of them. It was like piling every available object against a door to brace it against some menace from outside, [sic] when a well designed lock or cross bar would have served the purpose better.”[266] Efficiency and safety through simplicity in opposition to an increasingly

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[261] Lewis, *AECL-232*, 6.
[262] D. G. Hurst, *AECL-233: The Accident to the NRX Reactor on December 12, 1952. (Part II)* (Chalk River: Atomic Energy of Canada Limited, 1953), 151-152.
[263] Hurst, *AECL-233*, 152, 161-162.
[264] Lewis, *AECL-232*, 1.
[265] Laurence, *CA2ONRC75E6330*, 2.
[266] Laurence, *CA2ONRC75E6330*, 2.

specialized atmosphere became the new mantra of CANDU systems, as highlighted by John Foster's rolled joint anecdote that was a prelude to Chapter Two—highlighting how success through failure manifests itself in real technology as opposed to post-modern theories of zero-risk tolerance. Opinions such as those of Bertell have been painstakingly disproven and refuted with direct evidence since their rapid growth in the early 1970s. Anti-nuclear literature contains common fallacies, incorrect data, biased arguments and conclusions, and operates under a theoretical framework that cannot feasibly be introduced into any modern province.

Yet, some argue that these writers deserve the same platform as those who conform to practices of integrity and process. Michael Clow, a professor of sociology at the University of New Brunswick, argued in 1993 that the pro-nuclear establishment has been unfairly represented in mainstream Canadian media.[267] Clow argues it is the duty of the newspapers to print the perspective of the anti-nuclear establishment, no matter the accusations of lesser academic integrity.[268] He dismisses the notion that objective reporting is possible.[269] What is the harm in publishing what are labelled "unrepresentative" opinions when all opinions lack objectivity?[270] Clow closes his opening argument with the statement that anti-nuclear organizations and groups have created their own "independent nuclear expertise" and are mavericks lobbying "hostile politicians."[271]

This 'independent nuclear expertise' from Bertell and others has been dismissed as faulty. Sims dismantled more areas of this 'expertise' within *The Anti-Nuclear Game* (1990) than

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[267] Michael Clow, *Stifling Debate: Canadian Newspapers and Nuclear Power* (Halifax, N.S.: Fernwood Pub., 1993), 12-13.
[268] Clow, *Stifling Debate*, 13, 35.
[269] Clow, *Stifling Debate*, 17-19.
[270] Clow, *Stifling Debate*, 17-19.
[271] Clow, *Stifling Debate*, 28.

can be included here as it fills an entire monograph.[272] While sincere attempts at discussion of nuclear detraction deserve to be and are met with sincere responses, most arguments are admitted to be in bad faith. Between 1975 and 1981, the Ontario government funded the Royal Commission on Electrical Power Planning. The purpose of the Royal Commission was to decide how to regulate and oversee the nuclear energy industry in the succeeding decades. The Royal Commission called for evidence submitted from nuclear organizations such as AECL and Ontario Hydro and private interest groups such as the anti-nuclear figurehead, the Canadian Coalition for Nuclear Responsibility (CCNR). The Royal Commission accepted evidence and conducted hearings until it issued its recommendations to the province. The CCNR, the largest anti-nuclear organization in Canada, was chaired by Dr. Gordon Edwards, who participated as an expert witness and prominent participant in the Royal Commission. Edwards oversaw every opposition submission to the Royal Commission, which will be discussed below. When cross-examined by AECL lawyers toward the end of the process, Edwards admitted every anti-nuclear submission was neither information nor public information but propaganda "in the non-pejorative sense."[273] PANDA, a CCNR affiliate organization, then testified their information was "selective, biased, and misleading."[274] Upon cross-examination, PANDA's submissions were additionally found to be factually false.[275] PANDA representatives confirmed they would continue their anti-nuclear advocacy unchanged despite these findings.[276]

[272] Of particular interest are Chapter Two, Radiation and Health; Chapter Three, Nuclear Power Reactors; Chapter Four, Nuclear Fuel Waste; and Chapter Six, Nuclear Proliferation.
[273] Robertson, *AECL-6200*, 8.
[274] Robertson, *AECL-6200*, 8.
[275] Robertson, *AECL-6200*, 8.
[276] Robertson, *AECL-6200*, 8.

Additionally, groups such as CCNR and PANDA submitted their findings under their own definitions of risk, which differed from AECL's definition of risk. While anti-nuclear groups and theorists use the catch-all of 'dangerous,' they do not define what they mean. AECL used a specific, quantifiable definition of risk. AECL's definition of risk is the probability of an unrecoverable hurt - death.[277] Or dangerous failures of equipment that endanger the reactor or staff.[278] While pro-nuclear groups set out a clear definition of their premises, the anti-nuclear group did not define theirs. This resulted in an inherent disconnect within the debate, rendering the discussion flawed from the beginning. These preconceived agendas and ideologically motivated entrenching of opinions produce an immediately imbalanced and counterproductive basis for discussion within the Royal Commission. Additionally, the submission and hearings took place between 1975 and 1978. An independent survey conducted by York University's Institute of Behavioural Research in 1976 found that 44% of adult Canadians were unaware electricity from nuclear energy was possible.[279] Of the 56% aware of this possibility, two-thirds supported the use and expansion of nuclear energy.[280] Another survey was conducted in 1977 by AECL and found comparable results. The AECL survey also found 56% of the public was aware of nuclear energy's electrical capabilities (Ontario was 62%.)[281] Of the 56%, 68% favoured nuclear energy and of Ontario's 62%, 76% favoured it.[282] The team found that individuals responding negatively to nuclear power opposed it on an emotionally based fear response, low levels of public information, and a conflation between peaceful (nuclear reactors) and non-

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[277] E. Siddall, *CA9110414 – CA9110444: A Risk Perspective*, Presented at the CNS 1987 Canadian Engineering Centennial, (Toronto: Canadian Nuclear Society, 1987), 66.
[278] G. C. Laurence, *et al*., *Reactor Safety Practice and Experience in Canada*, Presented at the Third United Nations Peaceful Uses of Atomic Energy Conference. August – September 1964. Vol. 13. (1964), 317.
[279] Robertson, *AECL-6200*, 7.
[280] Robertson, *AECL-6200*, 7.
[281] J. E. O. Davies, J. K. Dobson, and R. G. Baril, *AECL-5714: Canadian Attitudes to Nuclear Power*, (Chalk River: Atomic Energy of Canada Limited, 1977), 3.
[282] Davies, Dobson, and Baril, *AECL-5714*, 3.

peaceful (nuclear weapons) use of nuclear technology.[283] A final study by the American EPA in 1980 found that the public rated nuclear radiation and waste as the top two safety concerns of the country, while EPA experts did not include them on the list due to their miniscule level of importance.[284] These findings support all claims made within this chapter thus far.

These surveys were conducted prior to the expansion of organizations such as CCNR and PANDA and the founding of Bertell's International Institute of Concern for Public Health, which operated between 1987 and 2004. As a result, the largely uninformed portion of the public had an increasing chance of consuming deliberately falsified data and bad-faith arguments that rely on their emotional responses as their introduction to the nuclear energy debate. Inculcating an environment in which Canadians increasingly respond with their 'gut' feelings on nuclear energy as opposed to a logical argument based on factual evidence. As the public became increasingly aware of nuclear energy, public interest groups such as CCNR and PANDA expanded their influence and rates of nuclear energy dissension rose accordingly. This has tangible effects on the Royal Commission, which will be outlined below.

Clow continues his argument in favour of prioritizing the anti-nuclear press by constructing a conspiracy that the nuclear industry was intentionally introducing radiation into the environment and stonewalling the public from this knowledge.[285] Firstly, the introduction of radiation into the environment from nuclear reactors has always been acknowledged and accounted for. As a result of stringent safety protocols and design features, the average resident near a nuclear power plant receives, on average, a similar dose of radiation as that of a television

[283] Davies, Dobson, and Baril, *AECL-5714*, 6.
[284] Sunstein, *Risk and Reason*, 53.
[285] Clow, *Stifling Debate*, 29-30.

set.[286] Secondly, Clow is entirely wrong in his assertion of secrecy. AECL was exceptionally active in publishing and providing public access to its technical publications. AECL published various annotated bibliographic technical publications grouped by research area. For example, *AECL-6186: Radioactive Waste Management in Canada: A Bibliography of Published Literature* was revised four times between 1975 and 1986. Containing 36 pages of bibliography and an index.[287] AECL-6186 is one of the dozens of such annotated bibliographies, and every bibliography and individual technical publication was available for purchase by private citizens, libraries, schools, and private institutions.[288] As stated within *AECL-6959*, the reason for excessive transparency was because "[AECL has] always recognized that it is equally important to understand what we are <u>not</u> doing and why, as it is to understand what we <u>are</u> doing."[289] (original emphasis) AECL set the standard for transparency within the Canadian nuclear industry. To assert that they intentionally obfuscated truths and created complex conspiracies to fool the public is morally reprehensible and willfully ignorant of reality.

AECL's insistence on transparency directly opposes the post-modern assertion that increasingly sophisticated technology would lead to an intentionally technocratic government. If technocracy were the goal of AECL and, by extension, the federal government, there would be incentives to withhold their technical publications from the public. Not to publish them freely and cheaply.[290] The growing divide between the lay population and the nuclear establishment

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286 Sims, *The Anti-Nuclear Game*, 41.
287 Norman J. Hawley, *AECL-6186: Radioactive Waste Management in Canada: A Bibliography of Published Literature* (Chalk River: Atomic Energy of Canada Limited, 1978).
288 For example, *AECL-6425: Fuel Cycles: A Bibliography of AECL Publications*, is another specialized bibliography. *AECL-6959: Some Highlights of Research and Development at AECL*, contains over 90 pages of general information and an annotated bibliography.
289 W. J. Langford and H. K. Rae, *AECL-6959: Some Highlight of Research and Development at AECL* (Chalk River: Atomic Energy of Canada Limited, 1980), 3.
290 It cost 25 cents to purchase a technical publication during the 1960s. AECL paid for postage. Lewis, *AECL-232*, 14.

was the opposite of what AECL wanted. Displayed within this paper are the facts that a population increasingly unable and disinclined to understand nuclear energy directly impeded the abilities of AECL to proliferate nuclear energy throughout Canada and particularly Ontario. The public produced the prerequisite factors for this divide and placed the blame squarely on the nuclear industry instead of themselves. Working against illogical, emotionally, and ideologically motivated resistance embodied by Clow was a constant theme for the nuclear industry.

Clow's final argument is his dismissal of affective heuristics and derision of the nuclear industry's ability to receive "criticism" from the media.[291] Clow derides the Canadian Nuclear Association's complaint that public perception was tangibly impacting the industry's performance as "incredible sensitivity… to criticism in the news."[292] Clow's statement is misleading and ignores multiple issues within the nuclear debate. Affective heuristics have been long established within psychology and repeatedly linked to tangible effects on industry, such as nuclear power, as shown repeatedly within this paper. Secondly, referring to the opinions expressed by the anti-nuclear establishment as 'criticism' gives them an unearned sense of authority. Criticism is always valid and welcome in technological research. In fact, it is essential. Without criticism, there are no objective failures and, thus, no advances forward through the success-through-failure concept. However, what the anti-nuclear establishment at large had done was not criticism. But self-referred propaganda and intentional misinformation.[293] Finally, the ten-second inaccuracy concept is increasingly relevant to this argument. The concept comes from Sims, who describes it as a statement that can (generally) be made within ten seconds but can

[291] Clow, *Stifling Debate*, 34.
[292] Clow, *Stifling Debate*, 34.
[293] Robertson, *AECL-6200*, 8, 74.

take up to 30 minutes of detailed presentation or the publication of an article to refute.[294] The technique is particularly effective during debates and any short-form content in which there is no time to offer a complete refutation. As a result, the refutation will have to be published or presented at a later date, sometimes months later, due to the speed of academic publishing. Meanwhile, the ten-second inaccuracy has become common knowledge through word of mouth or has cemented itself into the affective heuristic pathways of those present. Recall the example of plutonium lethality versus chlorine lethality described above. The inaccuracy and refutation were published over a decade apart. Giving more than ample time for the plutonium myth to flourish in the common consciousness.

Already established is the concept of affective heuristics. What happens when these affective heuristic shortcuts are combined with faulty reasoning and a population unable to comprehend the debate in question? It further feeds into post-modern thinking and paranoia. As Canadians are unable to keep up with the general discussion of nuclear power due to possible issues of comprehension, it triggers the heuristic response that the nuclear establishment is dismissing them with technocratic jargon, just as Grant said they would. Canadian nuclear energy has continuously proven to be one of the safest power technologies in the world. That CANDU, which was projected to be the defining technology of the century, would have ceased expansion and support by the mid-1980s speaks to the intensity of resistance it encountered. This chapter has sought to outline how post-modern notions of technology, risk, and general psychology coalesced into an undeserved scorning of nuclear technology. Without the

[294] Sims, *The Anti-Nuclear Game*, 25.

intersection of these factors, CANDU would almost assuredly have gone on to change the face of Canadian power production.

Conclusion

Opinion around nuclear energy rapidly changed during the late 1970s into the 1980s. In March 1979, the Three Mile Island nuclear plant experienced a meltdown in the state of Pennsylvania. This alone shook worldwide faith in nuclear power, but to worsen matters, the meltdown occurred a few weeks after the sensationalist movie *The China Syndrome* appeared in North American cinemas. This wave sustained itself until 1986 when the Chornobyl accident occurred, and the passion was reinvigorated. Canada lost successive international CANDU contracts from the 1970s to the 1980s, and faith in North American institutions eroded after the sensational Watergate scandal.[295] Both issues outweighed the nominal success of securing an Argentine and South Korean CANDU reactor. Nuclear energy suddenly had an intense image issue that was compounded by growing dissent from public interest groups. This undesirable reputation was worsened by the Canadian Federal Government's undecided and contradictory treatment of nuclear power during the 1980s. By 1981, a committee seriously suggested diverting resources from nuclear fission to nuclear fusion.[296] By January 1988, members of parliament called for an immediate moratorium on nuclear power, but by August, another committee had endorsed nuclear as "vital."[297] This confused dithering likely emboldened those who felt antagonistic towards nuclear power. If the government cannot decide if they support nuclear power, why should they? Especially in a post-Three Mile Island and Chornobyl world.

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[295] Bothwell, *Nucleus*, 424-431, 434.
[296] Thomas H. Lefebvre, *1980/83 A48 A12 Energy Alternatives*, Report of the Special Committee on Alternative Energy and Oil Substitution to the Parliament of Canada, (Ottawa: Library of Parliament, 1981), 169.
[297] Barbara J. Sparrow, *33-2 E554 A122: Nuclear Energy: Unmasking the Mystery?,* Tenth Report from the Standing Committee on Energy, Mines, and Resources (Ottawa: Library of Parliament, 1988), 3.; B. Brisco, 33-2 E58 A12 *High-Level Radioactive Waste in Canada: The Eleventh Hour*, Report of the Standing Committee on Environment and Forestry, (Ottawa: Library of Parliament, 1988 High-Level Radioactive Waste in Canada: The Eleventh Hour. 31, 37.

On the provincial level, further confusion and misunderstandings occurred. In 1981, the government of Ontario issued their final verdict in the years-long Royal Commission on Electric Power Planning. The forum in which groups such as the CCNR/OCNR and PANDA willingly admitted to falsifying data and producing propaganda was discussed in the previous chapter. The provincial government issued many verdicts. Some of which are of particular importance. For example, the provincial government accepted the recommendation that Ontario Hydro and AECL conduct a comparison analysis between CANDU and other nuclear systems to identify shortcomings in CANDU design. The report notes this recommendation was accepted because Ontario Hydro and AECL already engaged in these studies, rendering the recommendation moot.[298] Highlighting the nature of the debate between anti and pro-nuclear groups being one in which one side is not familiar with the basic practices of the other. The report later chastises the anti-nuclear plaintiffs for submitting multiple recommendations that are already in place.[299] However, the provincial government did accept a crucial recommendation. The then-in-development CANDU 1,250 MW reactor was to be immediately cancelled.[300] The works of the anti-nuclear establishment had come to fruition, new reactors were being cancelled, both the BLW and OCR had been shelved independently, and CANDUs were no longer being bought domestically. CANDU then went dormant and remained so until 2021. Despite Ontario CANDU's stellar record, they were unable to weather the complex and strong winds of cultural change.

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[298] Ministry of Energy, *CA8306491: The Response of the Government of Ontario to the Final Report of the Royal Commission on Electric Power Planning*, (Ontario: Ministry of Energy, May 1981), 25.
[299] Ministry of Energy, *CA8306491*, 29, 31.
[300] Ministry of Energy, *CA8306491*, 42.

In recent years, numerous SMRs (Small Modular Reactors, neither a CANDU nor Canadian design) and potential full-scale plants have been tentatively proposed in Ontario from 2021 until the time of writing in March 2024. Three additional SMRs would be built at the Darlington nuclear site.[301] Alongside the possible building of a new nuclear reactor complex at the Bruce site and confirmed refurbishment of the Pickering Nuclear reactors.[302] Ontario has additionally confirmed the reintroduction of radioactive isotopes into their reactors to produce enough material for millions of cancer screenings across the country.[303] These SMRs and new full-scale plants are not guaranteed to enter production at this time, and the soonest they can connect to the grid is 2030. Making the potential gap in new nuclear projects approximately 45 years. As detailed above, technology is an iterative and slow process. Built on preceding generations of knowledge. Without 45 years of continuous growth via success through failure and an unknown number of paradigm shifts, nuclear power's future in Canada is still entirely uncertain. Perhaps there will be a renaissance in the face of growing climate pressures riding the post-COVID-19 economic boom. Premier Doug Ford's Progressive Conservatives have already pledged $2 billion for the refurbishment of Pickering's nuclear reactors, not including the proposed SMRs and expansion of Bruce. CANDU proved itself once as a cheap, safe, and

[301] Ontario Power Generation, "Darlington," *Ontario Power Generation (OPG)* (Canada), 2024, Small modular reactors | Darlington SMR – OPG

[302] Colin Butler, "Ontario Wants to Expand Bruce Power, Canada's First New Large-Scale Nuclear Build in 3 Decades," *CBC News* (Canada), 5 July 2023, Ontario wants to expand Bruce Power, Canada's first new large-scale nuclear build in 3 decades | CBC News; Matthew McClearn and Jeff Gray, "Ontario to Announce Refurbishment of Four Reactors at Pickering Nuclear Power Plant," *The Globe and Mail* (Canada), 29 January 2024, Ontario to announce refurbishment of four reactors at Pickering nuclear power plant - The Globe and Mail

[303] Mike Crawley, "Ontario Nuclear Plant to Produce Material for Life-Saving Cancer Treatment," *CBC News* (Canada), 7 March 2024, Ontario nuclear plant to produce material for life-saving cancer treatment | CBC News; This essential portion of the CANDU program could not be included within this paper due to incompatibility with the project's scope. For an in-depth discussion of this sector, see Litt, Paul. *Isotopes and Innovation: MDS Nordion's First Fifty Years, 1946-1996*. Montreal; Published for MDS Nordion by McGill-Queen's University Press, 2000.

reliable domestic energy source. Perhaps the 2020s will be the decade in which its reputation precedes itself, and Ontario returns to its roots.

The purpose of this paper has been to detail the intersectionality of science and technology with the contextual era in which it finds itself. If technology progressed in a social vacuum, such as technological determinism suggested, almost assuredly, CANDU would have continued to progress steadily toward provincial and national dominance. Technological determinism has been proven false once again. CANDU had every quantitative and scientific fact weighed in its favour. Nuclear energy does not produce greenhouse gases, uranium supplies are steady and would last well into the next century, nuclear energy is safe, CANDU was designed and produced entirely within Canada, CANDU was a world leader in reactor and operator efficiency, and the technology was becoming near unimpeachable due to its decades of self-iteration via success through failure. Yet, what CANDU did not have in its favour was the blessing of the increasingly dominant post-modern thinkers and the public, who were increasingly coming under their sway. This single factor resulted in the dismissal of CANDU back to relative obscurity post-1980s. It is impossible to know what Ontario and Canada would have looked like if CANDU had not encountered this perhaps fatal resistance. However, with the hopeful news out of Ontario during the 2020s, perhaps a future generation will find out. These issues can easily resurface again. If the public is not given the tools to resist the draw of affective heuristics, if the public is not given the opposing theories to post-modern conceptions of technology, and if the scientific community does not improve in communicating how the scientific and technological process actually progresses, this chapter may reopen.

There has been almost a half-century between the twilight years of twentieth-century nuclear energy in Canada and the tentative revival of the 2020s. It is erroneous to think the human mind could have changed appreciably in that time when it is ostensibly the same as it has been for tens of thousands of years. What must change are the practices put in place to mitigate the chances of a repetition of the misguided resistance to Canadian nuclear energy that emerged in the 1960s-1980s. This comes from education first as the masses are not less intelligent than the nuclear establishment, merely a different level of informed and participatory. Combined with effective communication of the truth of nuclear power from knowledgeable experts. This would most likely take the form of commercials, news show appearances, social media marketing and educational TV series/episodes. It is common knowledge that the world has progressed even further into show business since Neil Postman's prophetic 1985 polemic, *Amusing Ourselves to Death*, and the nuclear energy establishment will be no exception from conformity. This would involve finding ways to combat Sims' 'ten-second inaccuracy,' logically opposing and dismantling fear and emotionally based heuristic inciting statements and educating the public on the reality of technology rather than letting the erroneous notion of Technology dominate the discussion. How this would practically manifest itself is beyond this paper's intended purpose.

This author firmly believes this line of thinking and the newly reforming opportunity for a dialogue between the two parties is of enormous consequence for the future of technology in Canada. This paper has hopefully outlined what went, in the view of a modernist, wrong with the nuclear energy discourse of the 1940s-1980s. With this paper now in existence, others can take the research in new directions with an unknowable array of ramifications. As new Ontarian nuclear projects are just getting underway, this conversation will likely unfold over the coming decades, not coming years. There is time for lengthy discussions between the various parties, but for those conversations to be fruitful, both sides must be able to communicate with equity and in good faith. The days of falsified testimony to oppose Technology have hopefully been left behind in the twentieth century. With the four-decade gap between nuclear projects, the slate has been cleared, and there is the unique opportunity to begin anew if those in power choose to.

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