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Submission from Anna Tilman

In the Matter of

Ontario Power Generation Inc.

Application to renew the Power Reactor Operating licence for the Darlington Nuclear Generating Station

Commission Public Hearing
Part 2

November 2-5, 2015

Exposé oral

Mémoire de Anna Tilman

À l'égard de

Ontario Power Generation Inc.

Demande concernant le renouvellement du permis d'exploitation pour la centrale nucléaire de Darlington

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Canada

Submission to the Canadian Nuclear Safety Commission (CNSC)

with respect to

Ontario Power Generation's (OPG's) Application for Renewal of its Operating Licences for the Darlington Nuclear Generating Stations for a 13-year term

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Prepared by

Anna Tilman
B.Sc., M.A.

With the assistance of

R. Gordon Albright
B.Sc., M.A., Ph.D

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Introductory Remarks

In 2012, an Environmental Assessment (EA) was carried out under the *Canadian Environmental Assessment Act* (CEAA, 1992) on Ontario Power Generation (OPG)'s proposal to refurbish and continue to operate the four reactors at its Darlington Nuclear Generating Station (DNGS), and extend their lives by approximately thirty years, to about the year 2055.

This refurbishment plan is a massive undertaking, both in the nature of the work involved and the time period. The public hearings that were held in 2012 on the proposed refurbishment provided many examples of problems that have occurred at refurbishment or rehabilitation projects carried out at other CANDUs in Canada, namely Bruce Power, Pickering and the Point Lepreau Nuclear Generating Station. Concerns were raised over the precarious nature of the work involved; the accidents that have happened and could happen during refurbishment, the majority of which is carried out by contract workers; the costs that would be incurred by this project and the very likely prospect of cost overruns and time delays, which have typically been double what was initially projected for other refurbishment projects; and whether refurbished CANDU units could be expected to operate safely and effectively for thirty years.

There were also concerns regarding the amount and type of radioactive waste resulting from refurbishment, including High-Level Radioactive Waste as well as Intermediate-Level Radioactive Waste that would contain transuranics and other long-lived radionuclides similar to that found in High-Level Waste. All this refurbishment waste would be in addition to the radioactive waste generated from the "routine" operations of the four reactors. The issue of nuclear waste is especially disconcerting, given that no technology has been found that is scientifically guaranteed to safely store nuclear waste for the hundreds of thousands of years that it remains hazardous. It is quite possible that no such technology will ever be found.

Further concerns were raised over the Ontario's continued reliance on nuclear power as a major source of energy for yet another 30-40 years, which prevents giving priority to conservation, efficiency and renewable energy, all of which are far less costly, very much cleaner, and very much safer.

Issues were raised over the overall safety and potential for accidents, including very serious ones, given the accidents that have happened at Fukushima, Chernobyl, and Three-Mile Island over a thirty-year period. Both OPG and the Canadian Nuclear Safety Commission (CNSC) dismiss such catastrophic events as unlikely to occur at Darlington, or for that matter, any other nuclear station in Canada.

Despite all these concerns and many more, in March 2013, the CNSC Commission concluded that refurbishment and continued operation of Darlington NGS, is not likely to cause significant adverse environmental effects taking into account mitigation measures identified in the Environmental Assessment Screening Report.[1] Subsequently, the operating licence for the DNGS was renewed twice, until December 31, 2015, to allow OPG sufficient time to complete the studies for refurbishment outages and to provide more documentation related to probabilistic safety assessments.

[1] OPG CMD 15-H8.1 p. 8, CNSC CMD 15-H8 p. 6

The preparation work for refurbishment at Darlington has already been underway for a few years, including the construction of the Darlington Energy Complex, which includes a full-scale mock-up reactor facility and a tool-testing facility for training purposes. Starting as early as 2014, contracts worth up to $1.5 billion have been awarded. [2] But there is no accounting for costs that are yet to occur. The residents of Ontario are in the dark as to what these costs might be, and that is totally unacceptable.

OPG has applied for a 13-year operating licence renewal which includes the continued operation and refurbishment of its four units at DNGS. The CNSC staff has recommended a ten-year licence period in order to align with the 10-year frequency recommended for periodic safety reviews.

These lengthy licence periods are unprecedented for nuclear power plants in Canada, which typically are no more than five years. They deny the public the scrutiny and transparency that this project requires, and greatly diminish the public accountability of reactor operators and regulators, which is essential to ensure public safety.

OPG and CNSC profess to have a "healthy" safety culture. However, this clearly shows otherwise. If an organization is convinced that it has achieved a safe culture, it demonstrates a lack of proper concern for safety. Safety culture is a product of continual striving. There are no final victories in the struggle for safety.[3]

CNSC's unequivocal conclusion that the refurbishment and continued operation at Darlington "is not likely to cause significant adverse effects on the environment" does not reflect a healthy safety culture, because it dismisses a great many valid concerns that have been raised.

In its presentation to CNSC August 19, 2015, OPG stated that "future generations will not be unduly burdened". But in 2055, OPG will shut down and mothball the Darlington nuclear station for nominally 30 years, and then begin the task of dismantling, demolition, and site restoration. This will take us into the 22nd Century. Certainly that is an undue burden on future generations.

OPG's 13-year licence application for refurbishment and continued operation is unacceptable and should not be granted. Likewise, a 10-year licence period is also unacceptable.

This is the time for the CNSC to take a precautionary approach and re-visit its conclusion with respect to refurbishment. The reactors at Darlington are nearing the end of their life. This is the appropriate and reasonable time to prepare for the phase-out of these reactors.

Given the issues that will be outlined in this submission with respect to OPG's refurbishment plans, the best option with respect to Darlington is for the CNSC to renew an operating licence that **does not include refurbishment** for a period no more than 5 years, that is the year 2020. In addition, we are requesting that the CNSC direct OPG to develop an accelerated detailed step-by-step decommissioning plan for the four reactors that would be subject to public consultation and scrutiny prior to the end of 2020.

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[2] http://www.power-technology.com/projects/darlington-nuclear-generating-station-refurbishment-ontario/

[3] http://www.ntsb.gov/news/speeches/rsumwalt/Documents/Sumwalt_121007b.pdf p.17 (with reference to a publication by Professor James Reason, 2000, p. 4)

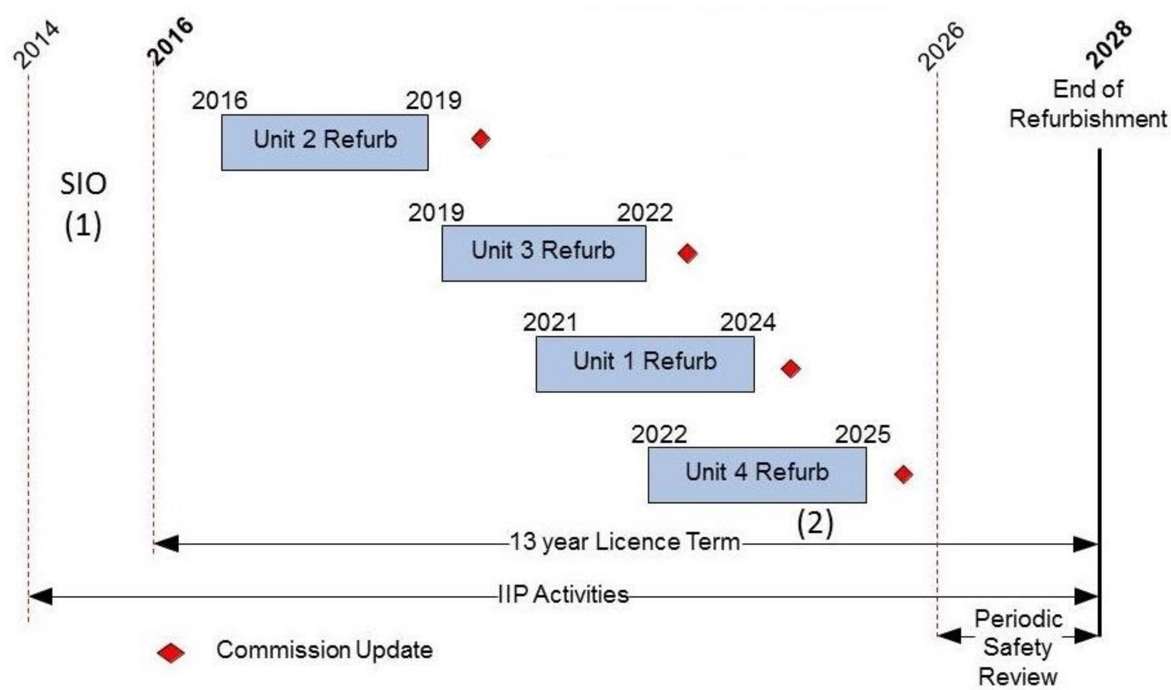
Refurbishment Timeline and Licence Duration

The refurbishment activities identified in OPG's Integrated Implementation Plan (IIP) include programmatic activities as well as unit-specific refurbishment activities and enhancements.

As indicated in OPG's submissions to the CNSC Commission on August 19, 2015, the timing for performance of the work activities depends on the safety precautions to carry out this work, the availability of resources to perform the work, and whether the work can be carried out at power or requires the unit to be in an outage state. Certain work activities planned during refurbishment require the units to also be defueled as well as shut down.[4]

The following Figure illustrates OPG's Darlington Refurbishment Timeline. It is based on OPG's current planning assumptions, including the 13-year licence period as requested by OPG. As indicated in the OPG's submissions, the timelines are subject to change.

Refurbishment Timeline and Licence Duration



Note: (1) SIO - Safety Improvements Activities and other Pre-Life Extension activities identified in the IIP
(2) Based on current planning assumptions

As noted in the Figure above, an update from the CNSC is to occur **after** each unit refurbishment outage. The nature of the updates is not clear. It is also not evident what level of public scrutiny would be made available in these updates or in the periodic safety review. Also, there is no discussion as to how these updates would affect the progress of refurbishment work on the subsequent Unit scheduled to be refurbished.

[4] CMD 15-H 8. 1A , p.33 and CMD 15-8.1 p. 11

The refurbishment of the 4 CANDU reactor units, scheduled one after the other within a very short window, is a massive, extremely complex undertaking. Nothing like it has ever been done before. It requires highly trained workers, the majority of whom will be contract workers, to carry out intricate and very dangerous tasks. There will be virtually no pause in this work, and this alone could have a serious impact on the quality of the work that needs to be done, potentially by the same trained workers repeatedly. This is not indicative of a "healthy" safety culture.

While OPG itself acknowledges that the timelines are subject to change, delays can and should be anticipated, based on past experience with refurbishing CANDUs. Have any studies been done to identify potential causes of delays, for example a shortage of supplies and equipment; limited trained workforce capacity; worker fatigue; weather conditions; or accidents or incidents at the site? What plans are in place to ensure that there is sufficient replacement power in the case of protracted delays?

How does OPG's application for a 13-year operating licence, with only periodic hold points or updates, address any of the problems that could develop in this work and the very real potential for delays and cost overruns?

Why has OPG produced such a tight schedule, when to all intent and purposes, it is unrealistic?

As noted, the CNSC staff has recommended a 10-year licence term (from January 1 2016 to December 31, 2015), to align with the recommended frequency of periodic safety reviews. The CNSC commission does have the authority to suspend, revoke or replace the licence. What situations could trigger such action?

OPG has indicated that the international practice is for long-term operating licences, even for the life of the plant. However, there is no indication of the nature and scope of these licences, or whether they are more prescriptive than the licence being proposed by OPG. Furthermore, CANDU reactors have unique features compared to other reactor designs, such as pressure tubes, the use of heavy water as a moderator, and the ability to re-fuel while the reactor is operating. [5] These features, especially the pressure tubes, could affect the longevity and long-term safety of CANDU reactors compared to other reactor types.

These lengthy operating licence periods proposed by OPG and the CNSC staff are unacceptable and inappropriate. They do not allow for proper public scrutiny or transparency, especially considering the nature, intensity and intricacy of the work required under refurbishment, the increased potential for accidents at the station, and the costs to the Ontario public.

Therefore, as has been stated in this submission, a fixed-term operating licence of a maximum of five years that does not include refurbishment is strongly recommended.

[5] https://www.oecd-nea.org/ndd/reports/2012/7054-long-term-operation-npps.pdf

Scope of Refurbishment

Fuel Channels and Steam Generators

The range of work involved in the "refurbishment" of a nuclear plant varies. According to the World Nuclear Association, refurbishing CANDU units consists of such steps as replacing fuel channels and steam generators and upgrading ancillary systems to current standards.[6]

According to OPG, "refurbishment requires the replacement of key reactor and station components, and will enable the Darlington station to operate for an additional 25 to 30 years."[7] The key activities included in the scope of refurbishment of the four units at DNGS include the replacement of fuel channels, feeders, calandria tubes, and end fittings, and other work including turbine generator upgrades, and the cleaning of the steam generators.[8]

Because the specific way that each activity will be done is not defined, a nuclear operator is free to decide whether to replace all critical components or to not replace all of them. As stated in OPG's licensing application;

"inspections will be conducted on the calandria internals to ensure the components that are not being removed are acceptable for continued operation." [9]

The aging of fuel channels (calandria and pressure tubes) is the single greatest cause of the declining performance of these reactors. These fuel channels are subject to deterioration and embrittlement over time, leading to rupturing.

Steam generators are the second greatest cause of performance problems. Steam generators incorporate thin-walled pipes (also called tubes) where coolant from the reactor core circulates to transfer heat to the turbine side of the station. These pipes constitute one of the primary barriers between the radioactive and non-radioactive sides of the plant. If a tube bursts while a plant is operating, radioactivity from the primary coolant system could escape directly to the atmosphere in the form of steam. For this reason, the integrity of the tubing is essential in preventing the leakage of radioactivity into the environment.

Steam generators are very sensitive to corrosion induced by chemical attack, and particularly to attack from deposits left by the concentration of boiler water contaminants. Problems with steam generators also include clogging of the pipes due to mineral deposits, 'fretting' or breakage of the internal pipes due to excessive vibration, and stress corrosion cracking of the metal that can result in the release of radioactive water.[10]

Replacing fuel channels is essentially re-building the reactor core, an operation characterized as a "heart transplant". Replacing steam generators is essential to protect the integrity of the radioactive/non-radioactive barrier.

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[6] http://www.world-nuclear.org/info/inf49a_Nuclear_Power_in_Canada.html
[7] http://www.opg.com/power/nuclear/refurbishment/dn_whatisrefurbishment.asp
[8] CMD 15 H8.1 p.9
[9] CMD 15 H8.1 p. 94
[10] Ontario's Nuclear Generating Facilities (Appendix 2) p. 113-114, 123: *A History and Estimate of Unit Lifetimes and Refurbishment Costs* May 2004 http://pubs.pembina.org/reports/appendix2.pdf

OPG has concluded that, "due to good chemistry management, the Steam Generators will remain fit for service over the life extension period and, therefore will not require replacement. The steam generator tubes and internals will be inspected, inspection nozzles will be installed and the steam generators will be cleaned to improve heat transfer." [11]

Rather than being replaced, the steam generators have slipped into a category of routine maintenance, inspections (which should be carried out in any case) and cleaning, and are expected to last yet another thirty years, an expectation that has no scientific basis.

According to a report by J.C. Smith of Babcock and Wilcox, the manufacturers of the Steam Generators for Darlington, Bruce and Pickering, there has been evidence of U-bend fretting at Darlington units. The effectiveness of cleaning steam generators by waterlancing is also questionable. Even with water chemistry improvements, inspections, and cleaning programs, problems with steam generators are known to persist. [12]

Another concern is that prolonged operation with degraded steam generators will ultimately increase radiation exposure and extended outages due to the increasing need for extensive tube inspection and repair.[13]

The units at Darlington will have been operating for 24-26 years by the time the proposed refurbishment commences. These issues cast very serious doubt on OPG's contention that the steam generators are fit for service over the life extension period, that is, for another thirty years.

Is the decision not to replace the steam generators an economic one?

The refurbishment of Bruce A Units 1 and 2 did include replacement of the steam generators. The steam generators at the DNGS are much larger than those at Bruce A, weighing about 340 tonnes compared to about 100 tonnes at Bruce. It would clearly be a very difficult and expensive task to remove these steam generators and to store them. If the cost of removing and replacing the steam generators and/or their storage is a factor in the decision not to replace them, then that must be disclosed. If one or more steam generators might fail, and have to be replaced, then the plan for refurbishment, the timelines and the costs, need to be revised to account for this.

Safety must prevail over expediency and cost. Replacement of key components including steam generators is not just a fall-back position, it is the only position to take in refurbishing a CANDU reactor. If that cannot be done, then refurbishment must not proceed.

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[11] CMD 15-H 8.1 p. 94

[12] http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/31/018/31018404.pdf; https://canteach.candu.org/Content%20Library/NJC-1-4-10.pdf; and http://www.power-eng.com/articles/print/volume-100/issue-1/features/steam-generator-replacement-overview.htm

[13] http://www.power-eng.com/articles/print/volume-100/issue-1/features/steam-generator-replacement-overview.htm

Fitness for Service - Pressure Tubes

Pressure tubes (PTs) are prone to aging problems due to the weight of the fuel bundles, the high temperatures, pressures and radiation fields in the reactor core, and corrosion. Over time, the tubes increase in length and diameter (known as diametrical creep), causing the walls of the pressure tubes to thin out and sag, primarily due to the weight of the fuel and coolant contained within them. They can come into contact with the outer calandria tube. This increases the chance of rupture of the PT caused by embrittlement of their metal walls from corrosion and the absorption of hydrogen.

The concentration of hydrogen in a pressure tube has the greatest influence on toughness. As the length of the operation time of the reactor increases, the accumulation of hydrogen results in the formation of blisters and cracks, a process referred to as hydrogen embrittlement. This can result in a short-term loss of toughness, and can also cause a stable, time-dependent crack growth mechanism called delayed hydride cracking (DHC) which has caused several failures in pressure tube components. The rolled joints at the ends of pressure tubes are particularly susceptible to deuterium pickup, primarily caused by corrosion in the crevices between the pressure tube and the end fitting.[14]

The design analyses of PTs take into account the dimensional changes of pressure tubes from the effects of creep and growth over a thirty-year period, which is their design life. But there is a point of no return. With the inevitable deterioration of the PTs, which leads to the degradation of the Heat Transport System (HTS) of the reactor, the safety margins of the operation of the reactor are compromised. This is why the tubes need to be replaced by the end of their designed life.

OPG plans to operate the Darlington units into the next proposed license period, so that while one unit is shut down for refurbishment, the other three units are fully operating. According to OPG's schedule for refurbishment, this would result in the likelihood of exceeding the current end-of-life of pressure tubes of 210,000 (210 k) Equivalent Full Power Hours (EFPH), for at least two units.

The following table provides projections for EFPH at the commencement of the proposed refurbishment starting dates.[15]

Unit	Start-up date	Refurbishment Outage Start date	EFPH at start of refurbishment
1	1992	March 2021	222k
2	1990	October 2016	188k
3	1993	October 2019	208k
4	1993	October 2022	227k

OPG has indicated that the Darlington fuel channel components are safe to operate to at least 235 k EFPH and that the CNSC has concurred with this position.

[14] http://www-pub.iaea.org/MTCD/publications/PDF/te_1649_web.pdf
[15] CNSC CMD 15-H8 p 55, 56, and OPG CMD 15-H8.1A p.40 slides.

According to the CNSC staff submission, the staff has verified that OPG has programs in place that support the continued operations for the Darlington pressure tubes to 235,000 EFPH and has stated that

“Operating beyond 235,000 EFPH is not a cliff-edge effect but is an indicator of when further assessment will be necessary. Given OPG plans to refurbish the Darlington NGS before 235,000 EPFH, further assessment to demonstrate operating beyond this point is not required.”[16]

In this same submission, it states that “Of all the aging and degradation mechanisms affecting the pressure tubes, hydrogen uptake and its reduction of fracture toughness is considered the dominant contributor to risk of pressure tube failure. Fracture toughness issues are only of concern during a very limited period of reactor operation; specifically, the transitions between shut down state to full power state and vice versa (heat up and cool down phases).”

Hydrogen uptake and fracture toughness are acknowledged issues in this statement, and this raises very serious concerns as to the safety of the pressure tubes, and extending their end-of-life. For example:

- Units 1 and 3, according to the proposed schedule, would exceed 210 k EFPH. But if there are any delays to this schedule, which is very likely, this would result in an increase in the EFPH of on average 7,000 -8,000 EFPH per year, based on the typical EFPHs for the Darlington units.[17] A two-year delay would result in Units 1 and 4 exceeding 235 k EFPH.
- Any inspections of fuel channels, in particular pressure tubes, on the units that have not been scheduled for refurbishment would result in a shutdown of that unit. Repeated shut downs and start-ups would increase the likelihood of further hydrogen uptake and fractures, especially in transiting between cooling and heating.
- The first unit scheduled for refurbishment, Unit 2, is the oldest unit, but has the lowest EFPH. Clearly, it is not the value of the EFPH alone that is driving the schedule, but more likely the condition of the key components, especially the pressure tubes. The PTs in this unit may have been damaged from fuel vibration problems in the early 1990, but no information has been provided as to the record of shutdowns (planned and unplanned) that has resulted in reduced operating time for this unit.
- In the case where there may be two units shut down simultaneously, because of planned refurbishment or planned or unplanned outages due to maintenance and repair, what back-up plans does OPG have for replacement power?

Is granting exceedances for the end-of-life of pressure tubes part of a healthy safety culture, or is it a matter of expediency to suit the “needs” of OPG regardless of safety?

[16] CNSC CMD 15-H8 p. 56

[17] Darlington Units 1-4 EFPH’s from 1990 – 2014: https://www.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=45

Waste Issues

OPG's proposed licence application includes continued operation of three out of four reactors during the 13-year period, while one reactor is shut down and being refurbished. As well, OPG expects that the life of the four refurbished reactors would be extended to 2055. Then the reactors would be decommissioned.

Throughout all this time, radioactive waste from refurbishment and continuing reactor operations will be generated. After the reactors are shut down, decommissioning waste will have to be dealt with.

Operational Nuclear Waste

If the Darlington reactors are refurbished as planned by OPG, and continue to operate for approximately 30 years after refurbishment, the Darlington NGS will generate:

- Operational Low Level Waste (LLW) at a rate of about 200 m^3 per reactor unit per year[18]; a total of 24,000 m^3.
- Intermediate-Level Waste (ILW) at an annual rate of 50 m^3/year total per 4 unit Darlington station[19]; a total of 6000 m^3.
- 22,000 fuel bundles of High-Level Waste (HLW, also referred to as spent fuel) each year[20].

Refurbishment Waste

Refurbishing the four reactors will produce significant amounts of radioactive waste. The ILW component will contain radioisotopes similar to those found in HLW.

OPG's plan for dealing with refurbishment waste is as follows:[21]

- The retube waste (i.e., the removed fuel channel components, including pressure tubes, calandria tubes, annulus spacers and end fittings) will be removed from the reactors, placed in shielded flasks and transferred to a new Retube Waste Processing Building (RWPB) at the Darlington NGS site.
- This waste will then be processed for volume reduction, and packaged into heavily shielded Retube Waste Containers (RWCs) as intermediate level radioactive waste (ILW). The containers will then be transferred, via truck, and stored at a new Retube Waste Storage Building (RWSB) on OPG property for approximately 25 years.
- At the end of this time, this waste will be sent to OPG's Western Waste Management Facility (WWMF) located at the Bruce Power Generating Station in Kincardine, Ontario and eventually to OPG's proposed Low- & Intermediate-Level Waste (L&ILW) Deep Geological Repository (DGR) at that same site.

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[18] Reference Low- and Intermediate-Level Waste Inventory for the Deep Geologic Repository, Ontario Power Generation, Page 49
[19] ibid
[20] Inventory of Radioactive Waste in Canada, Table 5.1: Nuclear Fuel Waste Accumulation Rate and Inventory, 2010
[21] CNSC CMD 15-H.8 p. 82; and OPG CMD 15-H8.1 p.79-81 and p. 100

- Other L&ILW generated during the outages will be collected and transported to a licensed waste management facility (e.g. the WWMF).

The ILW generated through refurbishment activities is estimated to include 3,860 m^3 of retube waste.[22] The main issue is the long-lived radionuclides contained in this waste.

Non-radioactive waste such as construction material will, where feasible, be re-used or recycled, and residual waste will be transferred to off-site disposal facilities. Any hazardous waste would be handled according to provincial regulations.

The Darlington Waste Management Facility (DWMF) will have to be expanded to accommodate the additional fuel waste during and after refurbishment.[23]

Ontario Power Generation and the Canadian Nuclear Safety Commission have provided very limited information about nuclear waste, and how it will be managed in the short, medium and long term. For example:

- OPG plans to place L&ILW generated during decommissioning “in the L&ILW Deep Geological Repository (DGR) … expected to be located in the Kincardine area”
- Used fuel will be stored in the Irradiated Fuel Bay, nominally for 10 years, and then moved into Dry Storage Containers (DSCs) for interim storage on-site; the Nuclear Waste Management Organization (NWMO) Adaptive Phased Management (APM) program, established by the federal government, is developing plans for a long term disposal facility for used fuel. [24]

Ontario Power Generation’s plans to manage L&ILW for the hundreds of thousands of years for which this waste will continue to be hazardous rely completely on its proposed Deep Geologic Repository (DGR) project. However, the final decision to build this DGR has not yet been delivered. OPG hasn’t even finished designing the project, and major outstanding technical and social issues pertaining to the proposed DGR still remain.

OPG’s plan for the long term safe-keeping of the High-Level Waste that will be generated by the extension of the Darlington nuclear operations is to hand it over the Nuclear Waste Management Organization (NWMO)[25]. The NWMO plan includes a multi-year multi-step siting process, and then centralizing the waste at a single location for either shallow or deep burial. There is no final design and many technical uncertainties and social issues are unresolved.

Clearly, OPG has no adequate plan in the short, medium or very long term to safety manage all the waste that will be generated by refurbishing the four reactors at Darlington, and the continuing operation of these reactors for another thirty years.

[22] CNSC Proposed Screening Report – DNGS Refurbishment and Continued Operation, Section 3.3.6, page 14
[23] CMD 15-H8.1 p. 108
[24] CMD 15-H8.1 OPG p. 80
[25] http://www.knownuclearwaste.ca/

Worker Health and Safety

The currently allowed level of exposure to ionizing radiation, referred to as the effective dose limit (in millisiverts, mSv) is 1 mSv/year for the public, and 100 mSv over 5 years, with a maximum of 50 mSv in one year for Nuclear Energy Workers (NEWs). These limits have been set by the International Commission on Radiological Protection (ICRP) and are used by the CNSC, Bruce Power, and OPG. In special circumstances, an effective public dose up to 5 mSv/year may be permitted.[26]

Licensees also set Action Levels (ALs) and Administrative Dose Limits (ADLs). ALs are designed to alert licensees before regulatory dose limits are reached, while ADLs are designed to ensure that individuals do not exceed regulatory limits.

Of particular interest is the difference between the ADLs for NEWs and contract workers (i.e., contract and building trade union employees). For Darlington (and Bruce Power), the ADL for contract workers is 40 mSv/year, twice the level of the ADL for NEWs (and OPG employees). With respect to Darlington, the ADL is 10 mSv/year for NEWs who have had a lifetime whole body dose greater than 500 mSv. This category does not apply to the contract workers.[27]

The Biologic Effects of Ionizing Radiation (BEIR) VII Report has concluded that there is a linear-no-threshold response to radiation, that is, that there is no threshold dose below which the risk of tumor induction is zero.[28] Thus, any level of exposure to ionizing radiation can cause harm. Thus these regulatory dose limits are administrative in nature, not health limits. In fact, the CNSC has stated that "the public dose limit of 1 mSv per year is a regulatory limit in the *Radiation Protection Regulations* – not a health limit. Dose limits have mistakenly been regarded as a line between what is safe and what is not safe".[29]

Routine maintenance and repair work, including the testing and measurement of components by Nuclear Energy Workers and contract workers, needs to be carried out on pressure tubes, feeder pipes, garter springs, etc., As the components age and the pressure tubes approach and exceed the original designed end-of-life, it will be all the more necessary to increase the frequency of monitoring, inspecting, and repair of components of the fuel channels.

This work could very well result in higher exposure of workers to all forms of ionizing radiation, and also to other hazardous substances which can impact heavily on the health of the workforce. Any work of this nature can lead to accidents, some very serious, placing front-line nuclear workers and contract workers at great risk.

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[26] http://www.hps.org/documents/publicdose03.pdf

[27] Reference for ADLs: Bruce Power; Licence Conditions Handbook (LCH) Radiation Protection June 2015 p. 62 and Darlington LCH 2015 p. 75

[28] BEIR VII report: http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/beir_vii_final.pdf

[29] Study of Consequences of a Hypothetical Nuclear Accident and Effectiveness of Mitigation Measures – CNSC draft report, December 2014 e-Doc 4449079 A0043878_000188

The work involved in refurbishment is that much more hazardous. The majority of refurbishment work is to be done by contractors. This is partly reflected by the higher ADL for contractors compared to OPG's NEWs.

All phases of the refurbishment project, including construction, defueling, replacement of reactor components, continued operation, the loading, transfer and storage of waste, the transportation of materials, and end-of-life shutdown, will impact heavily on the workforce. Many of the contract workers are likely doing these jobs on short-term contracts, but perhaps repeatedly for each of the four reactors.   This could well place them in a very hazardous position for total exposure to radiation.

Some of the most dangerous work is done manually. Many tasks can expose workers directly to ionizing radiation and radionuclides, such as the cutting and grinding of feeder tubes which caused the exposure of over 550 contract workers to alpha emitters during the refurbishment of Unit1 of Bruce A. Any accidents (spills, fires etc.) and emergencies also place these front-line workers at serious risk.

The contract workers are to receive training, but it is not clear how thorough this training will be, and whether the hazards of the work they will be carrying out and the potential for accidents will be properly explained. Will there be a strong focus on the risks of exposure to radiation? Will these workers have the option to opt out of a task if they feel that it is too dangerous?

According OPG's timelines in its IIP, each Darlington reactor will only be shut down for a very short period (6 months or a year) before the actual planned refurbishment work begins. This contrasts with the refurbishment at Bruce Units 1 and 2, which were shut down for approximately 10 years before refurbishment work was carried out. Thus, the radiation fields will be much higher at Darlington than they were at Bruce. The main source of reactor face fields is Cobalt-60 deposited on the inlet feeder pipes. Since Cobalt-60 has a half-life of about 5 years, a reactor has been shut down for 10 years, the activity will be 1/4 of its initial value. In the case of Darlington, there will be no significant delay from shutdown to refurbishment. The reactor face fields may be as high as 5mSv/hour.

In that case, according to the maximum annual dose limit for nuclear workers (NEWs), a worker could spend just 10 hours at the reactor face before exceeding the annual dose limit of 50 mSv. By comparison, the Bruce contract workers spent up to 30 hours at the reactor face in fields up to 1 mSv/hour, therefore receiving a dose of 30 mSv.

Not only will these workers be exposed to high levels of cancer-causing radiation, they will also be exposed to non-threshold carcinogens and other toxic substances. The cumulative, synergistic, and long-term effects on workers of their exposure to both radioactive and non-radioactive hazardous substances are not even recognized, let alone addressed.

What changes have OPG adopted in light of the alpha contamination of the contract workers at Bruce? What mechanism is in place to track the health of the contract workers in the long-term? How does OPG's safety culture justify this kind of work?

Safety Analysis - Methodology

The Probabilistic Safety Analyses (PSAs), and the models they are based on to determine the probability of an accident at a nuclear power plant, are not mathematically or scientifically valid for a great many reasons. First of all, a mathematical model is only valid, and can only give reliable results, if it is both complete and accurate. This means that it must take into account everything that might affect every number it is calculating, and must represent every last one of these essential factors accurately enough to give accurate final results. It is a well-known principle of mathematics (and computer science) that the final result of a computation is only as accurate as the <u>least</u> accurate number that went into it.

It is completely impossible to foresee everything that could cause a serious nuclear accident, let alone take it into account in a mathematical model. There's no telling what human errors might occur, such as the one that caused the accident at Chernobyl. The reactors at Fukushima were able to withstand a major earthquake, because the possibility was foreseen, but the resulting tsunami was larger than anyone foresaw, so adequate provision was not made for it. Just one oversight like this is enough to make any model that calculates the probability of a nuclear accident completely worthless, and it is impossible to avoid all oversights of this kind.

Furthermore, it is impossible to determine accurately the probabilities of all the accident scenarios that <u>are</u> foreseen. Just as logic and experience are the sole basis for all genuine science, so logic and experience are the sole basis for determining probabilities. There is no logical basis for determining the probability of any particular kind of human error, or act of terror, or a tsunami such as the one at Fukushima, or many other chance disruptive occurrences that might cause a serious nuclear accident. As we can never have long enough experience with nuclear accidents (without being destroyed by them first) to determine such probabilities on the basis of experience, there is simply no way to determine them accurately at all.

Finally, even if we could accurately determine the probability of a serious nuclear accident at the Darlington Nuclear Station, it would provide no guarantee of safety, no matter how small it was. Probabilistic predictions are only reliable when they are applied to a large number of cases. In a single case anything can happen at any time, even when it's highly improbable. As CNSC staff has admitted, its probabilistic risk models have no predictive value.

Following the accident at the American Three Mile Island nuclear station in 1979, an all-party committee of the Ontario Legislature (the Select Committee on Hydro Affairs) investigated Ontario's nuclear policies. In its 1980 report to the legislature, the committee concluded that:

> "Accidents, mistakes and malfunctions do occur in [CANDU] nuclear plants: equipment fails; instrumentation gives improper readings; operators and maintainers make errors and fail to follow instructions; designs are inadequate; events that are considered `incredible' happen...no matter how careful we are, we must anticipate the unexpected."[30]

[30] http://www.greenpeace.org/canada/en/Blogentry/can-a-nuclear-accident-happen-in-canada-quest/blog/33777/

Even when accidents are deemed possible and probabilities are estimated, they are not based on sound logic or experience because of an inherent bias that harmful events are either impossible or less than extremely unlikely.

A recent example of the failure of probabilistic risk analyses occurred at the Waste Implementation Pilot Project (WIPP) in Carlsbad, New Mexico in February 2014. The U.S. Department of Energy (DOE)'s risk analysis failed to consider the possibility that a container could be breached by a reaction or explosion within it. It estimated the probability of sustained combustion in a one-half full waste room to be 5.3×10^{-6} per year (that is, about once in 188,000 years) so it was deemed to be a less than extremely unlikely event.[31] But In just 15 years of operation, both a fire and a breach of a waste container explosion occurred at WIPP, and the facility remains closed.[32]

CNSC Study: Consequences of a Hypothetical Severe Nuclear Accident

The CNSC study, entitled "Study of Consequences of a Hypothetical Severe Nuclear Accident and Effectiveness of Mitigation Measures" (September 2015) involved modelling a large release of radionuclides to the atmosphere from a hypothetical severe nuclear accident (referred to as a generic large release) at the DNGS. The study estimated the human health and environmental consequences at various distances from the nuclear power plant, factoring in emergency response protective actions such as evacuation that would be caused by a severe nuclear accident.[33]

[Note: The September 2015 study included corrections to an earlier version released in August 2015 with respect to the amount of radionuclides that would be released in the event of a severe accident (Tables A1.1 and A1.2)[34]. The CNSC stated that these changes do not impact the conclusions of the report.]

CNSC used what is referred to as a "source term" (i.e., the quantities of all the radionuclides released to the environment) as the basis for the generic large release (GLR) used as a starting point for its study. This source term was representative of the contents of the reactor units at Darlington, and the amounts of radionuclides that would be released by an accident affecting all four reactors.

The "large release" used in this study is taken from REGDOC-2.5.2 *Design of Reactor Facilities: Nuclear Power Plants.* This document defines a large release as a release of radioactive cesium (Cs-137) greater than 1×10^{14} becquerels (100 TBq) over the duration of the accident.[35] Other

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[31] http://www.wipp.energy.gov/library/cca/CCA_1996_References/Chapter%209/CREL2441.PDF

[32] US DOE Report EEG-75 May 2000

[33] CNSC Study: http://www.nuclearsafety.gc.ca/eng/pdfs/health-studies/Severe-Nuclear-Accident-Study-eng.pdf; Note:

[34] Ibid: Table A1.1 gives the estimated radionuclide releases for the hypothetical nuclear accidents considered in this study and for previous nuclear accidents (that is, the source term); Table A1.2: Equilibrium Core Inventory of Isotopes Included in Dose Calculation. The CNSC stated that these changes do not impact the conclusions of the report.

[35] Ibid p. 17, 18. 1×10^{14} Bq Cs 137 = 0.152% of the initial DNGS Cs-137 core inventory of 6.7×10^{16} Bq (based on a single unit)

radionuclides are added to this large release to derive the source term and scaled to reflect the fission products associated with the Darlington reactors.

Synopsis of Findings and Conclusions of the CNSC Study: [36]

- For all hypothetical scenarios examined, doses would decrease rapidly with distance from the plant. From an emergency response perspective, for some scenarios, evacuations of up to 3 km would be needed. For the worst case scenario, evacuation beyond the Primary Zone, analogous to 12 km in this study, would not be required, based on the estimated doses.
- Human health results: The study found that it would be nearly impossible to distinguish most radiation-induced cancers (all cancers combined, leukemia, and adult thyroid cancer) from the baseline cancers assumed by this study. Childhood thyroid cancer was the only radiation-induced cancer that could be distinguished from baseline cancers. Increased risk for childhood thyroid cancer was predicted for all scenarios, which is not unexpected, given the sensitivity of a child's thyroid gland to radiation.
- The findings emphasized the continued importance of considering sensitive receptors (i.e., children) in emergency planning, such as KI pill administration.

Comments on the CNSC Study

While this study purported to be on the likely health and environmental consequences following a severe nuclear accident at the Darlington Station, the analysis and conclusions were based on an arbitrary, unrealistic and misleading "source term" (the quantity of every kind of radionuclide that the study assumed would be released to the environment in the event of a severe accident) that drastically understated how large this radioactive release was likely to be and downplayed the severity of the accident.

The CNSC study also had other serious flaws:

1) The CNSC's study is only a study of a hypothetical radioactive release, not of the kind of release that actually occurred after a "severe" accident such as Fukushima or Chernobyl. Thus, it did not accurately model the consequences of a severe accident, either immediate or long-term, on human health and the environment.
2) Numerous factors would be involved in determining the release fractions, that is, the amounts of particular radionuclides projected to be released as a result of a severe accident as fractions of the amounts that are in the core inventory. The basis by which these fractions (Table 3.1 in the Study) have been determined has not been made clear at all. What factors, such as chemistry, deposition patterns, wind direction, etc. have been taken into account? What range of scenarios for different fractions have been used? Did these fractions reflect the most serious, major accident that could happen? How arbitrary are the assumptions made in developing these fractions?

[36] Ibid: Extended executive summary; also OPG's CMD 15-H8.1 p. 44

- The release fraction for Cesium-137 (Cs-137) and Iodine-131 (I-131) is 1.52×10^{-3}, that is, 0.152 %. Based on the core inventory of Cs-137 (6.71×10^{16} Bq) and I-131, (2.94×10^{18} Bq), this would result in a large release value of 1×10^{14} Bq for Cs-137 (and 4.47×10^{15} Bq for I-131.) [37]

- Different release fractions of the core equilibrium inventory are set for different groups of the fission products (Table 3.1). However, the release fraction for both I-131 and Cs-137 is 1.52×10^{-3}. Why is the release fraction the same for these two radionuclides? Was the "large release" of 100 TBq Cs-137 back-calculated to yield this percentage?
- The Darlington "A' Risk Assessment Report (DARA 2015) stipulates that a very large release with potential for acute offsite radiation effects and/or widespread contamination is > ~3% of the core inventory of I-131.[38] This is about twenty times the percentage (0.152%) used in the CNSC study. How do the CNSC and OPG justify this very large difference?

The large release value for of radioactive cesium (Cs-137), greater than 1×10^{14} becquerels (100 TBq) over the duration of the accident, is not indicative of a major accident. This value is the smallest possible hypothetical release that can still be called "a large release", by definition.

Thus, the source term used in the CNSC study is very misleading. It does not represent the greatest possible radioactive release from the four nuclear plants at Darlington, and especially for a major or severe accident. By using such a low release fraction, the consequences of a major accident are drastically minimized.

3) The study notes that "Most of the radioactive material released from the core in such an event is anticipated to remain within containment and will not be released". [39] What is the basis for such a statement? How can a scientific study use such vague, imprecise terminology, as "most"?

4) As stated in this study, "the underlying goal has been defined in terms of avoiding undue public disruption, in the case of the large release of Cs-137, to avoid long-term relocation. The release of a greater magnitude is practically eliminated in light of the improvements emanating from the Fukushima Task Force."

   No valid study on the consequences of a nuclear disaster would arbitrarily limit the magnitude of the large release to ensure that it would not cause "undue public disruption", based on the completely unproven assertion that "improvements" emanating from the Fukushima Task Force had "practically eliminated" the possibility of a large release.

[37] CNSC Study: Table 3.1 p. 18, Table A 1.2 p. 88
[38] DARLINGTON NGS PROBABILISTIC SAFETY ASSESSMENT SUMMARY REPORT http://www.opg.com/generating-power/nuclear/stations/darlington-nuclear/Documents/DarlingtonNGSProbabilisticSafetyAssessment_SummaryReport.pdf p. 105
[39] CNSC Study p. 17

5) No actual accident scenario is specified or described in the CNSC study that would result in the precise hypothetical release, i.e., there is no discussion of what could go wrong inside the plant that could lead to such a release.

6) The CNSC study excludes the impact of early releases (within less than 24 hours) of radiation, which would be far greater in magnitude than later large releases (after 24 hours). Is this exclusion based on the assumption that no releases occur for the first 24 hours? What, if any, is the technical and scientific justification for such an assumption? What implications does this very serious omission have on emergency planning measures and the evacuation zones?

7) The accident at Fukushima is rated on the International Nuclear and Radiological Event Scale (INES) as a level 7 accident, the highest rating level on the scale of nuclear accidents.[40] Because it did not consider an accident of this magnitude, the CNSC study did not develop accident scenarios based on Fukushima, which was its intended purpose.

Unfortunately the CNSC staff and OPG do not seem inclined to take safety concerns as seriously as they should and must, presumably based on their conviction that a truly severe or major accident is so unlikely to occur that it will never happen. Such an attitude ignores the fact that probability has no predictive power when it comes to a single event. No matter how improbable an event may be, unless that probability is actually zero, the event could happen at any time, without any warning. Probability only tells you the frequency of such an event, and not when it will occur.

This attitude on the part of CNSC is inconsistent with the lessons of Fukushima, which dictate that even the most unlikely nuclear accident must be considered and planned for ahead of time if society is to be properly prepared to deal with the aftermath of such an accident.

The disaster at Fukushima has vividly demonstrated that not taking catastrophic accidents seriously leads to a lack of emergency preparedness, which makes a great tragedy for so many people even greater.

As stated by Toshimitsu Homma of the Japan Atomic Energy Agency, at IAEA Regulator`s Conference in Ottawa, April 2013

> "There was an implicit assumption that such a severe accident could not happen and thus insufficient attention was paid to such an accident by authorities."

Regardless of the risk of such accidents, the consequences are devastating. The institutional thinking that such accidents are too unlikely to happen is all too prevalent in the industry and the CNSC. It results in studies that have no credibility, and inadequate emergency preparedness that costs people their health and well-being.

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[40] http://www-ns.iaea.org/tech-areas/emergency/ines.asp The scale is designed such that the severity of an event is approximately ten times greater for each increase in level of the scale.

Event Reports – Public Accountability

Since 2003, Nuclear Power Plant operators in Canada have been required to submit “Event Reports” to the CNSC on a yearly basis. Initially, this came from the requirement in section 6.3 of the S-99 regulatory standard, *Reporting Requirements for Nuclear Power Plants*, to submit “Event Reports” (that became known as S-99 Reports).[41]

The S-99 reporting system included a preliminary report, which is a very brief description of the event. Depending on the severity or significance of the event, a detailed report and/or an additional information report was required, which included information already provided by the preliminary report (corrected if necessary), a summary of a root cause investigation, and corrective actions to be taken by the licensee to prevent any similar occurrence.

The regulatory document, REGDOC-3.1.1, *Reporting Requirements for Nuclear Power Plants*, published in May 2014, replaced the S-99 standard effective June 2015, with virtually the same requirements.[42]

However, the “Event Reports” that are publicly available on the websites of the operators and the CNSC are virtually useless. The only information provided is a list of the events that have occurred at a specific station for a specific year and report number, but there are no descriptions or accounts of investigations of these events.[43] So the public has no indication as to the cause of the accident/incident; its relative severity; or whether there were releases of radioactive and other hazardous substances to the environment. Access to actual reports would have to be requested, but there is no indication that they would be available on request.

The list of events excludes those considered to involve confidential or security-based information. While under Access to Information, a request can be made for documents about events containing confidential information, some of the information in these documents will still be redacted. This limits public access to reports of events beyond those submitted under REG 3.1.1. This leaves the public inadequately informed about these events, and whether or how they might have been affected.

Only those events that meet specific criteria are required to be reported to the CNSC. Even when an event is reported to the CNSC, its staff decides whether an event has enough “significance” to warrant further review by the CNSC Commission. It is not clear, at least to the public, what triggers the reporting of an event. For example, the exposure of workers to alpha radiation during refurbishment at the Point Lepreau Nuclear Station in 2009 was not reported to the CNSC because the predicted dose to workers was below the Action Levels set by New Brunswick Power Nuclear (NBPN), the operator of the facility.

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[41] Reporting Requirements for Operating Nuclear Plants (S-99 Reports) CNSC March 2003 http://nuclearsafety.gc.ca/pubs_catalogue/uploads/S99en.pdf (Criteria - p. 24, 25)

[42] https://cnsc-ccsn.gc.ca/pubs_catalogue/uploads/REGDOC-3-1-1-Reporting-Requirements-for-Nuclear-Power-Plants.pdf

[43] Event reports – OPG: http://www.opg.com/generating-power/nuclear/stations/Pages/Reports.aspx;
For example, the Event report for Darlington for the year 2014 is found at:
http://www.opg.com/generating-power/nuclear/stations/darlington-nuclear/Reports%20PDFs/Darlington_NGS-2014_S-99Reports.pdf

There is no indication that the reports as to the causes of an event are ever verified by an independent third party.

In light of the high level of public concern over the safety of nuclear plants, especially after Fukushima, and in the interests of public transparency and accountability, the current reporting requirements are totally inadequate.

The following important questions raise further issues about the inadequacy of the event reports:

1) What discussions have taken place publicly on these events?
2) How has the response to workplace injury (contamination) been handled?
3) How has the public been made aware of such events, especially those events that have resulted in releases of radionuclides and other hazardous substances into the environment?
4) What actions have been taken to remedy/prevent these events, especially those that are recurring?
5) What plans do CNSC and OPG have to improve reporting of events and be much more transparent?

Finally, the inadequacies of reporting and the lack of public transparency regarding events at the DNGS have serious consequences for the public. OPG and the CNSC must make the necessary efforts to achieve informative communication to the public on these matters.

Nuclear plants leak chronically and acutely. The extent to which this occurs must be made public. Withholding this information protects the industry, but not the public good, which is contrary to the mandate of the CNSC.

It is also not indicative of a strong safety culture, as continually professed by CNSC and OPG.

Emergency Preparedness

There are 10 nuclear reactors in Durham Region, 4 reactors at the Darlington station and 6 reactors at Pickering. These stations are approximately 36 km from each other. The Pickering units are reaching their end of life. OPG is planning to refurbish the 4 reactors at Darlington. That is a lot of nuclear activity close together in a highly populated geographical area.

If a severe worst-case scenario accident were to happen at either station today, any day, or during the planned refurbishment at Darlington, are essential emergency planning and preparations in place? For example:

Are the public alarm systems adequate and properly functioning?

Are the emergency planning zones appropriate and adequate?

Are evacuations plans able to handle the removal of so many people to safe sheltered areas quickly enough, especially if there is an early release (first 24 hours) of radionuclides?

What actions are planned to protect farmland and livestock?

What consideration has been given to the impact of the thousands of additional workers during the planned refurbishment of Darlington and the resulting increase in the number of vehicles, traffic, etc.?

Are there enough well-trained personnel on hand to ensure that there is a rapid response to an emergency?

Will workers at these nuclear stations be required to take heroic actions to try to mitigate damage to a reactor?

Is the management of a disaster well-coordinated?

Emergency Planning Zones

Emergency planning zones are geographic areas that require detailed preparations. Each planning zone requires different levels of preparation in the event of a nuclear accident. These zones are defined by circles of different diameters about a nuclear power plant. With respect to DNGS, the zones are as follows:

The Contiguous Zone: this is the area immediately surrounding the station from 0 to 3 km. Dominant features within this zone include a portion of Highway 401 and surrounding industrial and farming activities.

Primary Zone –This area includes the Contiguous Zone. It is the area within 0–10 km around the station. Detailed planning and preparedness for measures against exposure to a radioactive emission is required for this area, which has large population centres.

Secondary zone – This zone includes both the Contiguous and Primary Zones, and is the area within 0–50 km around the station. The planning and preparation for this area includes implementing ingestion control measures, such as monitoring the food chain for contamination, and banning the consumption of contaminated food items from this area. This zone encompasses areas of Durham Region, the City of Toronto, York Region, the City of Kawartha Lakes, and the counties of Northumberland and Peterborough.

The establishment of the measures that are required within each of these emergency planning zones (under the Darlington Nuclear Emergency Plan) is based on an accident of a 250-mSv whole-body effective dose at 1 km from the reactor.

Are the primary and secondary zones that have been established appropriate? Are they large enough in the event of a major accident?

Are these circular zones cutting off households improperly (because they may be living just beyond the periphery)?

How would changes in the dispersion and deposition of radiation caused by variations in wind patterns and weather conditions affect the delineation of these zones? Are there plans to broaden these zones?

Are there plans to deal with adverse weather and road conditions, especially during winter? Are there adequate provisions to provide safe food, drinking water, and medical assistance from professionals trained to treat the sick, those exposed to large amounts of ionizing radiation and to assist with the evacuation of large populations?

Evacuation and Sheltering

What special considerations are given to evacuating children, the sick, the elderly, and the handicapped?

Will changes in wind etc. be taken into account for evacuation? (For example, after Fukushima, the citizens of Iitate, 20 km beyond the 20 km evacuation zone, had to be belatedly evacuated due to radioactive deposition from a change in wind.)

Are there sufficient and appropriate safe sheltering buildings that offer protection against external radiation? Note: Buildings constructed of wood or metal (as opposed to solidly constructed buildings) are “not generally suitable for use as protective shelters against external radiation, and buildings that cannot be made substantially airtight are not effective in protecting against any exposures.”[44]

Evacuation Time Estimate Study

An evacuation time estimate study (OPG 2009a) was undertaken for the Darlington site, as part of the joint review panel for the construction and operation of new nuclear power plants at Darlington. This study has confirmed the anticipated evacuation time estimate (valid until approximately 2025) to be less than 9 hours from the 10-km emergency planning zone, which is considered to be well before the earliest time of an offsite radiation release from a severe accident at the Darlington site.[45]

This study accounted for the evacuation of approximately 250,000 people and 115,000 vehicles.

If evacuation were needed beyond the primary zone, what are the estimated times for evacuation for the secondary zone of 50 km, or even beyond?

[44] http://www.icrp.org/docs/ICRP_TG_Emergencies_draft_42_194_08.pdf
[45] CNSC Study p. 31.

These evacuation scenarios and plans are totally inadequate and unrealistic in many ways. A catastrophic accident would involve many more people from a much larger area. The congestion on the roads would make them almost impassable.

Bad weather conditions could have a massive effect on traffic. Finding protective shelters would be a most difficult task. Far too much is left for the individual to look after, including their basic needs such as food and water. Medical assistance and care would be essential. The most vulnerable would be the least protected. Confusion would reign.

Potassium Iodide (KI) Pills - Distribution

OPG is working with the Region of Durham, City of Toronto, and the Office of the Fire Marshall and Emergency Management on predistribution of KI pills to all residents, businesses, and institutions within the primary zone prior to the end of 2015. In addition, KI pills will be made available to residents within the 10 to 50 km radius (secondary zone), and stockpiles of tablets will be available for distribution by public authorities in an emergency, should it ever be required.

These new requirements are intended to ensure that KI is already on hand in the case of a nuclear accident. This is because the timeliness of ingestion of KI in the event of the release of radioactive iodine (I-131) is critical. Health Canada advises that KI is most effective to reduce the amount of radioactive iodine that would be picked up by thyroid glands if it is ingested just prior to or at the time of the first emission of radioactive iodine from a nuclear accident, with effectiveness very rapidly diminishing after that. In particular, protecting against radioactive iodine exposure is very important in the case of an early release of radioactive iodine.

Will the distribution of KI pills, which is slated for the primary zone and will be expanded to cover the secondary zone, be able to cover all people most likely to be affected by exposure to radiation, especially children, in the brief time period for which the pills are most effective?

The Planning Regime

Approximately 54 agencies are involved in emergency planning, including OPG, Durham Region the Province of Ontario (via the Provincial Nuclear Emergency Response Plan (PNERP)), the CNSC, Health Canada, etc.

In the event of an accident, OPG notifies the Province, CNSC, and the local municipalities, and is responsible for mitigating any effects within its boundaries. The province under PNERP is responsible for notifying the public about actions to be taken, issuing emergency bulletins to the public, sheltering, KI pill ingestion, and/or evacuation.

The CNSC requires major, licensed facilities, such as nuclear power plants to have effective emergency preparedness programs and associated emergency response plans. These licensees are required to conduct appropriate training, drills and regular exercises with all affected stakeholders to validate their emergency preparedness program.[46]

[46] CNSC Study p. 32

Carrying out evacuation and finding sheltering, in a time of high anxiety, requires the highest level of coordination, organization, and personnel. All the agencies involved in emergency planning must be coordinated, there must be strong oversight, and a state of preparedness and readiness at all times.

OPG is required to submit a transition plan for compliance with REGDOC-2.10.1 to CNSC staff by September 30, 2015, and be fully compliant by December 31, 2018.[47] There is no reason why OPG should be given more than three years to comply with a transition plan.

As the disaster at Fukushima has vividly demonstrated, not taking catastrophic accidents seriously leads to a lack of emergency preparedness, which makes a great tragedy.

Given that there are 10 operating nuclear reactors in the Durham Region, the potential impacts that a severe catastrophic nuclear accident could have on millions of people across Durham Region, the Greater Toronto Area (GTA), and beyond must be addressed seriously.

Unlike other severe industrial accidents, a nuclear meltdown is mass destruction for generations. This means that emergency planning and preparedness needs to include provisions to protect people, land, food, and the water after a nuclear plant accident. It must provide a robust public alarm system to warn residents of an accident, an effective evacuation and relocation plan, and adequate measures to prevent the ingestion of radionuclides from air, food, and water.

Extensive community outreach and education sessions on nuclear emergency plans for large releases and severe accidents are needed and should be conducted with increased frequency and the results of these actions made public in the community.

This world has experienced two reactor meltdowns in the last three decades, and emergency planning must take this into account. No nuclear facility should be allowed to operate without a coordinated, well-organized emergency plan that takes into account the worst possible accidents.

In summary, CNSC has a responsibility as a regulator to ensure that a coordinated, well-organized emergency plan is in place before granting an operating licence for DNGS. In fact, no nuclear facility should be allowed to operate without emergency plan that takes into account the worst possible accidents.

[47] CMD 15-H8.1 p. 76

Refurbishment of CANDU Reactors - Experience to Date

Refurbishment of CANDU reactors in Canada has been carried out or is ongoing at three nuclear stations, Pickering Nuclear, Bruce Nuclear Generation Station and Point Lepreau. The experiences to date have demonstrated that refurbishment, whether full or partial, runs into unforeseen incidents and accidents, resulting in delays, significant cost overruns, safety issues and in some cases, excessive or unnecessary exposure of workers to radiation.

This section highlights information on accidents/incidents during refurbishment or any rehabilitation activities; any exposure to radiation or other hazardous substances to workers as a result of these activities; and measures (if any) taken in response to these events. Also included is a summary of estimated costs associated with these refurbishment activities.

a) Bruce Power – Bruce A

Bruce Power was engaged for a number of years in a project, the Bruce A Restart Project, which includes the refurbishment and restart of CANDU nuclear Reactor Units 1 and 2 at the Bruce A Nuclear Generating Station.[48] Both of these reactors were shut down in the 1990s, (Unit 1 in 1997 and Unit 2 in 1995). On Oct. 17, 2005, Bruce Power reached an agreement with the Ontario Power Authority and launched a $4.25 billion investment program to refurbish and restart Bruce A Units 1 and 2. The actual work got underway in 2006. Refurbishment of these two units included the replacement of 16 steam generators.

Between November 24 and December 21, 2009, as part of the refurbishment of Bruce A Unit 1, building trades workers were engaged in the cutting and grinding of feeder tubes, part of the heat transport system, in one part of the Unit 1 reactor building (called the "reactor vault"). Feeder tubes supply cooling water to each of the individual pressure tubes which contain the uranium fuel, and thus are one of the critical support systems of the reactor.

Prior to this specific task, in 2008, a section of each feeder tube had been cut out and had to be replaced. The work in 2009 (referred to as "J-prep") consisted of removing the magnetite layer from the inner and outer surfaces of the cut ends of the feeder tubes in order that a clean surface would be available for welding the replacement piping.

At the time that the work began, no continuous air monitoring was in place. The only monitoring in place consisted of periodic grab sampling of the air in the reactor vault, using a portable air sampler. Two of the samples, taken the mornings of November 26 and November 28, indicated spikes of airborne long-lived radioactive particulate in the general work areas of the reactor vault.[49]

However, measurements carried out on these samples only showed the amount of beta-gamma radiation that was present in the reactor vault (due to Cobalt-60) at those two points in

[48] For a full account of the alpha incident and the responses and actions by Bruce Power and the CNSC, refer to CMD 15-H2.110 Submission from Eugene Bourgeois and Anna Tilman April 2015 p. 87-97

[49] S-99 Additional Information Report, CNSC B-2010-28184910 A1, April 29, 2010; Radiation Safety Institute: Final Report, July 14, 2011 [Final Report], p. 29, 30 RSIC-Final-Report.pdf
Levels measured: 7.5MPCa (Maximum Permissible Concentration in Air) and 5.0 MPCa respectively.

time. No measurements were done on not alpha activity. As was later revealed, alpha activity was also present in the air when these spikes occurred, but there was no capability on site to detect it directly.[50]

The workers who were cutting and grinding these pipes were not aware that the dust created by their work contained alpha-emitting radionuclides that were traveling into the general atmosphere of the vault. Thus, any worker in the vault would inhale this dust and unknowingly be internally exposed to alpha radiation.

Consequently, over 550 workers were unknowingly exposed to airborne particulate containing long-lived alpha-emitting radionuclides (e.g., Pu-238, Pu-239, Pu-240, Am-241 and Cm-244) from fuel debris that had been previously released from a defective fuel bundle.

On November 28, 2009, a plastic tent was constructed around the prep work area. Work resumed on the grinding. However, the effectiveness of the plastic tent to contain the airborne particulate was never tested. Subsequently, an investigation revealed that the tent was poorly sealed and was not effective in controlling the spread of contamination. As a result, the airborne particulate spread far beyond the immediate work area and throughout the general vault atmosphere, and workers were exposed to alpha-emitting particles for a period of almost 4 weeks. [51]

While the workers involved in the prep work itself wore plastic suits, as required by the Radiological Exposure Permit (REP) for the job, and were protected from the airborne contamination, this was not the case in other sections and elevations of the reactor vault, where many other jobs were also underway. Many other workers in the reactor vault were not required to wear respiratory protection for the particular jobs they were doing and were unprotected from the airborne alpha contamination.

Internal exposure to alpha radiation is particularly hazardous. If alpha-emitting radionuclides (alpha-emitters) are inhaled, ingested, or absorbed in the bloodstream, sensitive living tissue is exposed to alpha radiation. The resulting biological and genetic damage increases the risk of cancer and other illnesses. In particular, alpha radiation is known to cause lung cancer when alpha emitters are inhaled.[52]

On February 19, 2010, in response to a joint request from the Provincial Building and Construction Trades Council of Ontario, Bruce Power, Comstock Canada (representing the construction companies at Bruce A Restart) and Atomic Energy of Canada Ltd (AECL), the Radiation Safety Institute of Canada (RSIC) agreed to provide independent and impartial assistance regarding this incident. This work was funded by Bruce Power.

The findings and conclusions of this root cause analysis clearly acknowledged Bruce Power's negligence by its failure to provide adequate oversight and analytical preparation prior to the J-prep work. It further indicated that a strong safety culture was absent during this period. In addition, the expertise of other operators was not sought out before beginning the operation,

[50] RSIC-Final-Report.pdf Executive Summary, and p. 46
[51] Final Report RSIC-Final-Report.pdf p. 27-30
[52] http://www.epa.gov/radiation/understand/alpha.html#exposure

with the predictable result that an accident such as this was likely to occur. Thus, Bruce Power was totally unprepared to deal with the alpha airborne particulate hazard, because it failed even to consider its possibility or likelihood. This demonstrated a totally inadequate safety culture.

The cause of the accident and increase in alpha activity was eventually traced back to a fuel channel that was accidently crushed during re-fuelling operations on April 19th 1979, which resulted in the release of up to 4 kg of Uranium Dioxide (UO_2) into the Unit 1 Primary Heat Transport System (PHTS) [53]. Radiation fields around the Unit 1 heat transport system increased five-fold due to the deposition of this radioactive material in the system.

At a public hearing held December 9, 2010 in response to the accident at Bruce A Unit 1, the cause of the alpha contamination was found to be that "the high ratios of beta-radiation to alpha-radiation in potential contamination produced during normal operations led to the reliance on protecting for beta radiation as a means to also provide protection against possible alpha radiation."[54] This was clearly incorrect.

At this same hearing, another alpha contamination incident that had occurred during refurbishment activities at the Point Lepreau nuclear reactor operated by New Brunswick Power Nuclear (NBPN) was disclosed. "On February 25, 2009, during removal and crushing of the third pressure tube, the continuous air sampler in the west vault went into alarm due to malfunction of the active ventilation system." Alpha contamination, primarily due to Curium-244, was confirmed. However, because the predicted dose was below NBPN action levels, it was not reportable to the CNSC.[55]

b) Refurbishment Activities at Other CANDU Facilities (Canada)

i) Bruce A - Units 3 and 4

A program was set up to restart Units 3 and 4 of Bruce A. These units were laid up in 1998. Unit 4 was returned to service on November 28, 2003 and Unit 3 on March 28, 2004. [56] Unit 3 underwent an upgrade from November 2011 to May 2012 to extend its life by ten years. According to Bruce Power, "When needed, Unit 3 will undergo a similar refurbishment with new steam generators and fuel channels, while Unit 4's steam generators are expected to be replaced as required."[57]

ii) Point Lepreau

In mid-2005, a decision was made to refurbish New Brunswick's Point Lepreau reactor, located on the Bay of Fundy. The reactor had been in commercial operation since 1983. It was the first Candu-6 reactor to undergo refurbishment. NB Nuclear Power (NBPN), a crown corporation and

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53 Refer to Bruce NGS In-Service Report BNGSA-IR-33000-7: "*Unit 1 P13 Fuelling Incident – Monitoring of Heat Transport System*", October 1979; and RSIC Final report

54 CNSC Document CMD 10-M72 November 23, 2010

55 Ibid p. 25

56 Communication from CNSC October 11, 2012

57 http://www.brucepower.com/3986/news/news-archive-2005/agreement-reached-to-secure-bruce-power%E2%80%99s-future/

operator of the Point Lepreau Nuclear Generating Station, and Atomic Energy of Canada Ltd (AECL) were responsible for the refurbishment project.

Refurbishment activities included replacing all 380 fuel channels, calandria tubes and feeder tubes, as well as other maintenance work at the station. The project was to extend the life of the Point Lepreau reactor by about 25 years, the length of time that it had been operating.

The refurbishment work began in March 2008, and was to be completed eighteen months later, by September 2009. But things did not go as planned.

From the very beginning, the project was plagued by a myriad of technical glitches, the most critical being that the new calandria tubes were faulty. These problems caused numerous delays, resulting in several revisions in the time and cost estimates for the refurbishment. The project was extended more than three years beyond the original 2009 restart date.

The removal of the 380 used calandria tubes in the reactor and the installation of new ones is one of the first and most significant activities of refurbishment. Between December 2009 and April 2010, all 380 new tubes were installed, and the 760 end joints connected and sealed. But many of the tubes repeatedly failed air tightness tests after being fused with special inserts designed to hold them in place. Eighty failures were detected during tests of the tubes. AECL acknowledged that the tubes and their inserts weren't smooth enough to form a consistently tight seal, and that polishing the ends would have made them fit tighter. [58]

On October 9, 2010, AECL announced that all 380 of the new calandria tubes had to be removed and replaced, and the tubes sheet polished to ensure an adequate fit. This task involved removing the 760 calandria tube inserts that held the tubes in place; removing the 380 tubes; polishing and cleaning the tube sheet bores; and then inserting the new calandria tubes.

This work took over a year to complete. On completion of the re-tubing activities, barring unforeseen circumstances, NB Power planned to proceed with commissioning activities. This was expected to "take approximately four months in order to safely return the reactor to service in the fall of 2012, ready for the heating season." [59]

NBPN did not include full replacement of the steam generators as part of its refurbishing of Point Lepreau. While about 1,500 corroded, deteriorated, embrittled and wall-thinned tubes of the steam generators were replaced, about 20,000 tubes were not. The state of deterioration of these tubes is not known, making the steam generators the weakest link in the primary cooling circuit.[60]

[58] http://www.cbc.ca/canada/nbvotes2010/story/2010/09/22/nb-lepreau-pc-promise.html#socialcomments

[59] World Nuclear Association (WNA) November 30 2010 http://www.world-nuclear-news.org/C-Point_Lepreau_refurbishment_schedule_achievable-3011105.html

[60] Transcript of Point Lepreau re-licensing hearing December 2011, Dr. Gordon Edwards http://nuclearsafety.gc.ca/eng/commission/pdf/2011-12-02-Transcription-Hearing.pdf

In February 2012, the CNSC renewed the operating licence of the Point Lepreau Nuclear Generating Station for five years and gave permission to the facility to reload fuel and restart the reactor. In July 2012, the CNSC authorized NBPN to begin activities to restart the station.[61]

NBPN had planned to have the reactor return to service and start generating electricity in the fall of 2012. However during the testing of the nuclear reactor's rebuilt systems required for regulatory approval to put it back in service, one of the main output transformers connecting the plant to provincial transmission lines crashed. [62] The plant was finally returned to service in November 2012, but it is not problem-free by any means.

The work has cost one billion dollars more than the $1.4 billion originally estimated, and another one billion dollars has been spent on replacement power due to the delays.

Historically, the radioactive waste produced by the station has been stored on site. The radioactive waste volumes from refurbishment have been much higher than anticipated, because of the unforeseen problems that occurred. This has left inadequate storage for the additional waste produced during the extended life of the station. NBNP is considering options such as entering into a contract to incinerate all “old waste”, building additional storage, and transferring waste to a third party for “ultimate disposal”.[63]

The only other CANDU 6 reactor that has been refurbished is Wolsong Unit 1 in South Korea.[64] In 1996, 96 fuel bundles failed in this reactor because of insufficient baking of the graphite coating. [65]

iii) Pickering

Pickering A, consisting of 4 reactor units, went into service in 1971. Pickering B, also 4 units, began commercial operation in 1983. After only 12 years of operation, on August 1 1983, Reactor 2 of Pickering A was shut down following a metre-long rupture in one of its pressure tubes. The rupture was due to embrittlement caused by hydrogen absorption into the tube alloy. The remaining three units were shut down in succession. All four units underwent “retubing” (pressure tube replacement), a procedure that stretched out to 1993. Subsequently, all four units were shut down again in 1997 because of technical and performance problems.

Thus began the second “refurbishment” or rehabilitation of Pickering A, but only for Units 4 and 1. These units were returned to operation in 2003 and 2005 respectively, with a renewed life expectancy. The Provincial Government decided not to refurbish units 2 and 3, presumably due to costs incurred in this second round of repair work, although safety may have also have played a role in this decision.

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[61] CNSC links: http://www.nuclearsafety.gc.ca/eng/mediacentre/releases/news_release.cfm?news_release_id=402 and http://www.nuclearsafety.gc.ca/eng/mediacentre/releases/news_release.cfm?news_release_id=418

[62] http://www.cbc.ca/news/canada/new-brunswick/story/2012/09/05/nb-point-lepreau-delays-829.html

[63] Refurbishment Implications on Long-Term Waste Management Strategies at Point Lepreau, Charles Hickman Point Lepreau Generating Station – International Waste Conference 2011 .

[64] http://www.world-nuclear-news.org/C_Korean_Candu_restarts_after_refurbishment_2907114.html

[65] IAEA Nuclear Fuel Series, Review of Fuel Failures in Water-Cooled Reactors 2010 p.32 http://www-pub.iaea.org/MTCD/publications/PDF/Pub1445_web.pdf

In February 2010, OPG decided against full refurbishment for the four Pickering B reactors, and instead spend $300 million to keep them going for another 10 years or so, before finally closing and decommissioning them. [66]

iv) Gentilly-2

In 2008, Hydro-Québec announced plans to refurbish its only operating nuclear reactor, the Gentilly-2 CANDU-6 nuclear reactor. [67] The costs for the proposed refurbishment were estimated to be about $2.5 billion. Re-estimations by Hydro-Québec placed the costs of this refurbishment at about $4.3 billion, based on the experiences of other refurbishment projects at two CANDU-6 reactors, one being the Point Lepreau Reactor.

In light of the prohibitive costs of refurbishing, Hydro-Québec has concluded that "the refurbishment project is not justified on economic grounds." On October 4 2012, Hydro-Québec confirmed that it would close Gentilly-2 by the end of 2012.

c) The Costs of Refurbishing

i) Experiences to Date

Estimates for refurbishing (or "retubing") nuclear reactors have been notoriously unrealistic, resulting in tremendous cost overruns at all nuclear stations (Pickering, Lepreau and Bruce Power) that have engaged in that activity. For example:

Pickering: [68]

- The initial re-tubing of all four Pickering A units during the period from 1983-93 cost $1 billion - more than their original capital cost.
- The cost for the Pickering 1 retubing in 2004-05 was approximately $ 1 billion, more than double the original estimate. The Ontario government decided to retire units 2 & 3 rather than refurbish them, as these units were considered uneconomical to refurbish.
- The estimated cost for restarting Pickering 4 alone was $1.25 billion, more than five times the original estimate of $230 million.

Bruce A: [69]

- Units 1, 3 and 4 were shut down in 1998, while Unit 2 was shut down in 1995. Units 3 and 4 were restarted between 2003 and 2004, following an investment of approximately $725 million. This was more than double the original estimate for repair work on these two units. [70]

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[66] This estimate has been revised by OPG to $200 million www.opg.com/power/nuclear/pickering/
[67] http://montreal.ctvnews.ca/hydro-quebec-to-shut-gentilly-2-nuclear-plant-in-december-1.982629
[68] World Nuclear Association [WNA] Info sheet: http://www.world-nuclear.org/info/inf49a_Nuclear_Power_in_Canada.html, http://pubs.pembina.org/reports/appendix2.pdf p 122-7
[69] http://www.powerauthority.on.ca/nuclear/bruce-restart-and-refurbishment-project-3000-mw-tiverton;WNA
[70] http://pubs.pembina.org/reports/appendix2.pdf p. 122

- The October 2005 agreement between Ontario Power Authority and Bruce Power estimated the costs to restart Units 1 and 2, refurbish Unit 3 and replace the steam generators of Unit 4 at $4.25 billion, of which $ 2.75 billion for Units 1 and 2, and the balance for Units 3 & 4.[71] On August 29, 2007, the agreement was expanded to include the full refurbishment of Unit 4, at an additional cost of $ 1 billion. Then in 2008, the cost for refurbishing Units 1 and 2 was further increased by $350 million to $650 million over the original forecast of $2.75 billion. This amount was later "upgraded" to $4.8 billion.
- The estimate for fixing /refurbishing Bruce A's 4 units ranges anywhere from $5.6 to $ 8 billion. But that is not a recent estimate.

Duncan Hawthorne, Bruce Power's President and CEO, stated that "he recalled saying in 2005 that the project would come in on time and on budget. Instead, it took twice as long and cost twice as much."[72]

Lepreau:

Refurbishment has cost one billion dollars more than the $1.4 billion originally estimated, and another one billion dollars has been spent on replacement power due to the delays.

ii) Darlington - the estimated cost of refurbishment?

This question has not been answered by OPG or the Province. The statements made to date by these bodies are vague and non-committal. For example; [73]

- The Ontario Minister of Energy had placed refurbishment costs in the range of $6-10 billion as a preliminary bounding estimate.
- In 2012, OPG indicated that it would not be prudent to speculate on a potential cost when construction is many years away and so many variables, outside of OPG control, might impact that estimate. The final timeline and cost will not be known until the regulatory and technical scope is determined, engineering is completed, construction contracts are signed, and a release quality cost and schedule is developed. This should be completed by 2015. Once that work is complete, OPG will have confidence in the scope, cost and schedule of the project.

In other words, no estimates with any substance have been provided by the Ontario government or OPG. Even the range indicated as a preliminary estimate is very wide, and has not been evaluated by any third party. Such was the case with the building of the Darlington reactors, which were initially estimated to cost $4 billion, and came in at $10 billion over budget.[74]

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[71] http://www.powerauthority.on.ca/nuclear/bruce-restart-and-refurbishment-project-3000-mw-tiverton The agreement signed between the Ontario Power Authority and Bruce Power is known as the Bruce Power Refurbishment Implementation Agreement (BPRIA)

[72] http://www.independent.on.ca/site/?q=node/4049

[73] http://www.opg.com/power/nuclear/refurbishment/dn_factsheets.asp

[74] http://www.greenpeace.org/canada/en/campaigns/Energy/end-the-nuclear-threat/Resources/Fact-sheets/What-you-need-to-know-about-Darlingtons-reactors/

In its presentation to the CNSC on August 19, 2015, (CMD 15-H8.1 A, p. 9), OPG referred to "Investments (~12.8 Billion) in major safety improvements and long-term safe, clean power for Ontario". That is hardly an estimate of the costs for their planned refurbishment.

In projecting costs for refurbishment, no allowances are made for;

- The costs of fixing any breakdowns that might occur.
- Replacement power costs during extended shutdowns to repair unforeseen problems.
- Replacement power costs if the reactors don't operate as long after refurbishment as overly optimistic estimates by the industry say they will.
- The costs to human health and to the environment.

There is absolutely no guarantee that these reactors will last 25-30 years after being refurbished. There is no experience anywhere to suggest that this is possible. In all experience so far with any level of refurbishment, it has simply not been worth all the time, effort, and money that have been spent to get refurbished units up and running, only to have serious breakdowns occur long before their projected lifetime after refurbishment. Repairing these breakdowns is always very expensive. If these repairs are not worth what they cost, then the reactor does not last as long as projected, and does not produce all the power that was projected. All Ontarians are left to pay for this.

Refurbishment has always ended up costing much more than it is worth and taking much more time than it was supposed to. This is why the operators of nuclear power stations and government authorities are so unwilling to reveal its true costs.

These exorbitant costs without any public accountability are unconscionable. No other business or industry would ever bring in such unrealistic forecasts of expenditures, and run up costs that far exceed these estimates. If they did they would go bankrupt. But the nuclear industry is given a blank cheque by governments, while the residents of Ontario pay the price for many years.

Concluding Remarks

The mid-life extension of DNGS will require the refurbishment of 4 reactors within a span of about 13 years, as estimated by OPG. This will be a massive project, one-of-a-kind, and one of the most intensive carried out on nuclear plants anywhere in the world. Just the refurbishment of one CANDU unit has resulted in serious problems, accidents (including the internal exposure of over 550 workers to alpha particles at Bruce Power), cost overruns, and delays. Far greater problems can be expected when four units are to be refurbished in succession.

To continue on this refurbishment path is costly, potentially very dangerous, and unnecessary. It is especially dangerous for the many contract workers who will be carrying out most of the refurbishment. It will add greatly to our inventory of radioactive waste, when we have no safe storage solution for it. Future generations, who will have not had electricity that was generated by nuclear power, will be left with its problems. That is unjust.

OPG and the CNSC staff are convinced that severe accidents at Darlington or other nuclear power stations in Canada are unlikely. This has been expressed over and over again in the submission documents, in spite of the nuclear disasters at Chernobyl and Fukushima, whose consequences are still unfolding and will be for many years. This steadfast belief that an accident cannot happen drives further nuclear expansion, at the same time as it makes a serious accident more likely and reduces our preparedness for it.

Because such accidents are considered to be unlikely events, there is no proper preparation for them. Hypothetical severe accidents are modelled using assumptions and values that do not represent a severe accident, such as the one in Fukushima. Adverse health effects are never predicted (except for children perhaps) even if a severe accident were to occur. The nuclear industry and the CNSC are in complete denial regarding adverse health effects caused by nuclear power plants, even to the point of claiming that no deaths could be attributed to Fukushima, and minimal fatalities have resulted from Chernobyl, even though it still has a 30 km exclusion zone.

The emergency plans that have been developed so far are totally inadequate for a major accident at DNGS, let alone, a catastrophic one.

OPG's application for a 13-year operating relicensing for Darlington that would include refurbishment would not just commit Ontarians to rely on these reactors for 13 or so years, but for three or more decades as far out as 2055. If approved, this will make Ontarians dependent on nuclear power for another 40 years which contrary to industry claims, is not clean, cheap or safe.

But the aftermath of the use of nuclear power would not end in 2055. The reactors would have to be mothballed for at least thirty years, and then decommissioning would begin. Not only would future generations inherit the radioactive waste from refurbishment, there would be enormous waste resulting from decommissioning that would need to be managed somehow – though it is not evident how. This will go on into the 22nd century. All this nuclear waste, from the operation of nuclear plants, refurbishment and decommissioning, is a legacy that no government or company should be allowed to leave for future generations.

The possibility of accidents, including very serious ones, must be a major concern with any nuclear facility. However, there is clearly an intrinsic bias on the part of the nuclear industry, the Provincial Government and the CNSC not to seriously consider the possibility of accidents, because this would jeopardize nuclear power projects, and threaten existing nuclear power plants with closure.

It is abundantly clear that the lessons of Fukushima have not been applied. This is very disturbing, especially when the Fukushima accident happened just over two years ago, and its effects will be felt (like those of Chernobyl) for many decades at least. Fukushima has provided the strongest and most recent demonstration that a nuclear power station can cause devastating harm.

To presume that “it can’t happen here” is the height of arrogance and ignorance. It can happen anywhere, at any time, for countless reasons, which can’t all be foreseen or prevented. Fukushima has also demonstrated how important it is to have adequate and effective emergency plans in place. This is especially pertinent to a multi-unit facility such as the Darlington Nuclear Station.

In conclusion, there is no justification whatsoever for proceeding with licensing Darlington for a 13-year period or even a 10-year period, as recommended by CNSC staff. Such long licence periods are unacceptable, unnecessary, risky, and an impediment to public scrutiny.

Therefore, OPG’s 13-year licence application for refurbishment and continued operations should not be granted. Instead, it is recommended that OPG be granted a renewal of its operating licence for the Darlington Station **that does not include refurbishment** for a maximum period of 5 years. During this period, OPG would be required to develop a detailed plan for decommissioning its four reactors that would be subject to public scrutiny and consultation.

Clearly, the proposed project has a negative impact on developing adequate renewable resources to meet the needs of the present and the future. Nuclear power plants are very expensive, produce deadly radioactive pollution and create the risk of devastating accidents that cost far more than the power they generate will ever be worth. This calls for a nuclear phase-out and a planned transition from nuclear power to renewable energy, which is the safest and most responsible path to take.

As Benjamin Goldman, an economist, has said [75]

> Governments and agencies responsible for sanctioning nuclear operations have made a rather odious gamble with human life – potentially resulting in millions of cancer deaths and similar nonfatal afflictions to innocent bystanders, many of whom have not even been born. This is discounting the value of an untold number of human lives. Future generations will be forced to take man-made risks that have nothing to do with their well-being.

[75] Goldman “Discounting Human Lives” p. 247-8

Appendix

Health and Safety Issues

Standards and Guidelines for Radiological Substances

Over the years, as more has been discovered about the hazards associated with certain substances, and the effects of radiation, standards have become more stringent. The limits that are currently in place are very likely to change with increased knowledge and awareness of the harm they can allow for present and future generations. Indeed, many of these standards have been criticized for years for not being protective or precautionary. Just because emissions lie within or below current standards does not mean that they do no harm.

The methodology for determining standards and limits must shift from the current approach to one that reflects and ensures the utmost precaution and protection of the health of the entire public, and especially of the most vulnerable populations within present and future generations.

CNSC, as Canada's nuclear regulator, is responsible for regulating nuclear facilities in order to protect the health and safety of workers, the public and the environment. Upholding current limits that are flawed and outdated, such as the public dose limit of 1 mSv/year for exposure to ionizing radiation, or the Canadian drinking water guideline for tritium of 7,000 Bq/L, harms public health, rather than protecting it as the mandate of CNSC requires.

The currently allowed level of exposure to ionizing radiation for the public is 1 mSv/year, and for nuclear energy workers it is 100 mSv over 5 years with a maximum of 50 mSv in one year. These limits have been set by the International Commission on Radiological Protection (ICRP) and are used by the CNSC and OPG.

1) First and foremost, there is no safe level of exposure to ionizing radiation. This has been clearly acknowledged in the National Academy of Science series "Biological Effects of Ionizing Radiation", the BEIR VII Report on *Health Risks from Exposure to Low Levels of Ionizing Radiation*, which concluded that dose-response to radiation follows a Linear No-Threshold (LNT) model. Thus, there is no dose for which there is no risk.[76]

2) Radiation damage can affect any part of a cell, and can interfere with many cellular processes. Damage to the genetic material of the cell can lead to cancer, non-cancerous tumours, birth defects, hereditary illness, and immune system diseases. While this damage can sometimes be repaired by mechanisms within the cell, that is not always the case. Damage to eggs or sperm can be passed on to future generations.

3) Basing risk assessment on fatal cancers alone does not take into account other radiation-related health effects.

4) Radiation from internal emitters is very different from external radiation, and far more dangerous. If a radioactive particle is inhaled or ingested, that particle will continue to

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[76] http://www.cirms.org/pdf/NAS%20BEIR%20VII%20Low%20Dose%20Exposure%20-%202006.pdf; see also BEIR VII report: http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/beir_vii_final.pdf

emit radiation as long as it is in the body and the particle remains radioactive. When a person is exposed externally to a source of radioactivity, the exposure lasts only as long as the person remains close to the source of radiation. In addition, alpha radiation from an ingested radioactive particle causes far greater harm than external alpha radiation.

5) Not all people exposed to radiation are affected equally. These limits do not make proper allowance for the most vulnerable members of society, foetuses and children. At these life stages, individuals are far more sensitive to radiation than in adulthood. Most of our standards are based on adult exposures.

6) Some radionuclides may bioaccumulate in an organism and biomagnify, i.e. build up in the food chain. For example, they reach higher concentrations in fish or seafood than in the surrounding environment, thereby posing a greater risk to anyone or any species eating the contaminated food than the surrounding water would.

7) Radiation-induced bystander effect creates the possibility that extra-nuclear and extracellular effects may also contribute to the final biological consequences of exposure to low doses of radiation. [77] This issue is of particular concern among genetically susceptible populations.

Clearly, the ICRP limits are neither safe nor protective. The approach developed by the ICRP to determine the dose limits is used primarily because it can quickly convert a multidimensional problem into a linear calculation that can readily be used in making management decisions.

These limits are not based on worker health or public health criteria. Rather, they are based on the degree of harm to human life and health and to the environment that is "acceptable" or tolerated by regulatory bodies in return for the "benefits" of the activities. Ultimately, from a public health standpoint, the maximum safe dose of any ionizing radiation is zero.

Health Studies – Review and Critique

a) Health Effects of Radiation on Nuclear Workers

The International Agency for Research on Cancer (IARC), a 15-Country Nuclear Worker Study published in 2005, assessed cancer risks following low doses of ionizing radiation. The study, the largest worker study ever conducted, examined over 400,000 nuclear energy workers (NEWs) who wore a radiation dosimeter or badge, and who worked for at least one year in the nuclear industry in one of the 15 countries, including Canada.[78]

The IARC study found a small but significant increase in cancer risks, especially leukaemia, at the dose-rates typically received by the nuclear workers in this study. It also found that NEWs

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[77] **NIH Program Project on Radiation Bystander Effects: Mechanism;** Columbia University Center for Radiological Research www.radiation-bystander.columbia.edu/

[78] Ethel Gilbert, Radiation Epidemiological Branch, National Cancer Institute: *Epidemiological Studies of Nuclear Workers* May 16, 2007 (IARC Report: Cardis et al. 2005) http://radepicourse2007.cancer.gov/content/presentations/slides/GILBERT_Workers_slides.pdf Refer also to http://www.nuclear-free.com/PDF/TAP_Fact_Sheet.pdf http://www.iarc.fr/en/media-centre/pr/2005/pr166.html

from Canada had the highest excess relative risk of mortality from all cancers excluding leukaemia among the 15 countries, and this risk was statistically significant.[79]

A previous study conducted by Zablotska et al., specifically on the same Canadian nuclear workers that contributed to the IARC study, found that the relative risk/Sievert was higher for Canadian nuclear workers than for other nuclear workers and for the Atomic bomb survivors. [80]

A plausible explanation for the higher cancer risks for Canadian workers could be an under-estimation of the exposures to tritium in part or all of this population could be due to CANDU reactors which use heavy water as a moderator and thus would emit more tritium than other reactor designs. [81]

The CNSC's June 2011 report on verifying the radiation risk for Canadian NEWS was essentially criticism and dismissal of the findings of the IARC study.[82] If the CNSC were truly concerned about protecting the safety of Canadian nuclear workers, it would take every indication of possible risk extremely seriously, rather than dismissing it.

b) Radiation and Health – Durham Region Report 2007

The 2007 report by the Durham Region Health Department is an update of a previous version in 1996 on the health effects resulting from operations at the two nuclear stations, Pickering and Darlington, in Durham Region. These stations are situated on Lake Ontario a mere 28 kilometres apart. Radiation and Health in Durham Region 2007 is an ecological study of the rates of various cancers, congenital abnormalities, and stillbirths in areas surrounding the Pickering and Darlington Nuclear Stations.[83]

As it is an ecological study, which examines rates of illness at the level of the community, and not individual cases or situations, no conclusions about causation are possible. There were also other limitations to the study, for example, the failure to include pancreatic cancer as an endpoint outcome; the broad age range (0 to 19 years) applied to the childhood cancer category; and the influence of confounding factors (for example, growth and migration of population in the region) which cannot be adequately dealt with in an ecological study.

In general, this report ignores so many potential paths for exposure to radiation and so many harmful consequences of such exposure, and its basic methodology is so weak, that its failure to identify any significant harmful consequences provides absolutely no scientific proof that people, above all nuclear workers, are not being harmed.

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[79] CNSC Report 2011 http://nuclearsafety.gc.ca/pubs_catalogue/uploads/INFO-0811-Verifying-Canadian-Nuclear-Energy-Worker-Radiation-Risk-A-Reanalysis-of-Cancer-Mortality-in-Canadian-Nuclear-Energy-Workers-1957-1994_e.pdf p.5

Zablotska I.B., Ashmore J.P., and Howe G.R: *Analysis of mortality among Canadian Nuclear Power Industry Workers after chronic low-dose exposure to ionizing radiation. Radiation Research* 161: 633-641 (2004). http://www.jstor.org/discover/10.2307/3581008?uid=3737720&uid=2129&uid=2&uid=70&uid=4&sid=21101139987693

[81] Dr. Rosalie Bertell: *Health Effects of Tritium*, Submitted to the CNSC, November 27, 2006

[82] http://nuclearsafety.gc.ca/pubs_catalogue/uploads/INFO-0811-Verifying-Canadian-Nuclear-Energy-Worker-Radiation-Risk-A-Reanalysis-of-Cancer-Mortality-in-Canadian-Nuclear-Energy-Workers-1957-1994_e.pdf

[83] Durham Region Health Department, Whitby Ontario: *Radiation and Health in Durham Region 2007*

However some worrisome results were noted in the Report, including an increase in leukaemia in males, elevated bladder cancer mortality, and increased incidences of breast and thyroid cancers and Down's syndrome.[84]

Few studies of merit have been done on the health effects of living in close proximity to nuclear stations in Canada. This is especially a concern with respect to tritium, as Canada releases more tritium than any other country in the world due to the heavy water used in CANDU reactors.

It is well known that ionizing radiation causes cancers. It is scientifically impossible to release massive numbers of radionuclides without causing any harm, especially when internal exposure to a single radioactive atom can be deadly.

c) The Radicon Study

The CNSC study entitled: *Radiation and Incidence of Cancer Around Ontario Nuclear Power Plants from 1990 to 2008,* commonly referred to as the RADICON Study, published in May 2013, was an ecological study of populations living near Ontario's three nuclear power plants (NPPs). Its purpose was to "determine the radiation doses to members of the public living within 25 km of the Pickering, Darlington, and Bruce NPPs and to compare cancer cases among these people with the general population of Ontario from 1990 to 2008".[85]

The RADICON Study concluded that:

> "There is no evidence of childhood cancer cluster (especially childhood leukemia) near the threes NPPs studied. Overall, for all ages, there is no consistent pattern of elevated cancer incidence at any of these three NPPs; this finding is consistent with previous studies. …some types of cancers were found to be elevated in some communities (but never at all three sites), and some types of cancer were found to be lower in some communities….Overall the cancers are well within the natural variation of disease within Ontario". [86]

The Study did note a number of limitations of ecological studies, for example:

> "Associations at the population level do not necessarily reflect the biological effect at an individual level. Uniform doses are assigned to the group whereas the doses received by individuals vary, and are also very uncertain", and that "limitations of ecological studies prevent any causal inference to be made".[87]

By grouping the population within 25 km of each nuclear power plant (Pickering, Darlington and Bruce) into a single category, this Study lacks the sensitivity and definition of other existing epidemiological study designs, such as the German KiKK case-control study on childhood

[84] Dr. Cathy Vakil M.D., C.C.F.P., F.C.F.P; Dr. Linda Harvey B.Sc., M.Sc., M.D. *Human Health Implications of Uranium Mining and Nuclear Power Generation* May 2009 p.35-38

[85] The RADICON Study, CNSC May 2013 Summary: http://nuclearsafety.gc.ca/eng/pdfs/Reading-Room/healthstudies/Radiation-Incidence-Cancer-Around-Ontario-NPP.pdf

[86] Ibid p. 13

[87] Ibid p. 19

leukemia. [88] Thus, the RADICON Study is not able to determine whether there are health effects caused by radiation doses to the public from nuclear power plants.

The statement that "Radioactive iodine (I-131), which is the primary cause of radiation-related thyroid cancer, was below detection limits of the in-stack sampling monitors at all three NPPs for the entire study period" is not valid.[89] CNSC reports on radioactive releases from Canadian NPPs show these plants typically release 2×10^8 Bq of I-131 per year.

Averaged meteorological data coupled with averaged annual emissions were used to estimate doses to members of the public living near Canadian Nuclear Power Plants (NPPs). CANDU NPP's emissions are not constant. They are dominated by short-term spike releases and therefore subject to far less dispersion than long-term "routine" emissions. In addition, doses resulting from the wet deposition of radionuclides, especially from spike releases that coincide with periods of heavy precipitation, are inevitably underestimated by long-term averaging.

The authors of the RADICON Study admit that a process of "*dose reconstruction*", rather than direct measurement, was used to investigate cancer epidemiology in the vicinity of NPPs in Ontario. This process involves modelling the dispersion of radionuclides in air and water using computer algorithms.

These limitations demonstrate the extreme weakness of the RADICON Study. While the Study refers to Sir Bradford Hills' criteria for demonstrating causality, it violates a critical principle that Dr. Bradford Hill identified, namely, "conclusions about cause and effect relationships must be based on assessment of multiple criteria and application of sound reasoning, not on slavish adherence to one criterion or to any algorithmic model."[90]

Negative findings in such a weak study should not reassure the public that there is not an increase in childhood leukemia in the proximity of nuclear plants in Ontario.

d) The KiKK Study

Childhood Leukemia and Cancers near German Reactors[91]

A childhood leukemia cluster was first reported in the late 1980s in the vicinity of the nuclear plant Krümmel near Hamburg. In response to citizen's concerns, the German government conducted an ecological health study of all German nuclear plants over an 11-year period (1980-90). Exploratory analyses of this study showed a statistically significant increase in acute leukemia in children younger than 5 years of age who lived less than 5 km from these plants. Another study found a non-significant increased risk for acute leukemia this population subset.

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[88] Spix C., Schmiedel S., Kaatsch P., Schulze-Rath R., Blettner M. Case-Control Study on Childhood Cancer in the Vicinity of Nuclear Power Plants in Germany 1980-2003. Eur. Journal of Cancer 2008; 44:275-284; also http://www.bfs.de/en/kerntechnik/kinderkrebs/kikk.html

[89] Ibid p. 12

[90] http://skeptvet.com/Blog/2010/01/hills-criteria-of-causation-what-separates-science-from-faith/

[91] Rudi Nussbaum Portland State University, Portland, OR, USA: Childhood Leukemia and Cancers Near German Nuclear Reactors: Significance, Context, and Ramifications of Recent Studies INT J OCCUP ENVIRON HEALTH 2009; 15: 318-323; and http://www.psr.org/chapters/oregon/assets/pdfs/halifax-talk-08.pdf

However, these ecological studies work with *population averages*, and can only suggest, but not confirm or deny, a causal relationship between living in the vicinity of nuclear power plants and higher incidence of childhood cancer cases.

In 2002, in response to the controversial findings, the federal childhood cancer registry, known in Germany as KiKK, initiated a case-control study of childhood cancer cases in the areas around all 16 nuclear reactors to confirm or negate whether childhood malignancy cases *do not increase* with proximity to nuclear power plants. The credibility of the KiKK study was enhanced by the appointment of a prestigious independent review committee of 12 scientific experts: 5 epidemiologists, 2 paediatricians, 2 statisticians and 3 physicists.

The study found a statistically significant continuous increase in the incidence of excess childhood leukemia and cancer cases within a radius of 50 km from the 16 German reactors, which was greater the closer the children lived to a nuclear plant at the time of diagnosis. Children living 5 km or less from a nuclear plant were found to be 27% more likely to develop a malignancy than children living farther than 5 km. Such a consistent correlation around all 16 reactors is a strong indicator for a causal relationship.

Yet the KiKK scientists concluded:

". . . based on current radio-biological knowledge and epidemiological studies [of health effects of radiation], the emitted radioactivity from normally operating German nuclear power reactors can on principle not be interpreted as having caused [the observed excess in leukemia and other cancers in children]" and

". . . [since] possible confounders could not be identified, the observed positive distance trend remains unexplained."

This counter-intuitive interpretation of the study's findings by its investigators is in line with repeated claims by the World Health Organization (WHO) and the International Atomic Energy Agency (IAEA) that documented findings of excess cancers, neo-natal mortalities, spontaneous abortions and other health detriments all over Western Europe, even at large distances from the 1986 Chernobyl disaster, could not possibly be associated with its radioactive fallout ,since population exposures, as estimated by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) were several factors of ten too small to cause the reported detrimental health effects.

However, the 12-member independent external review panel criticized the KiKK investigators for ignoring the findings of several other radio-epidemiological studies which were remarkably consistent with their own data, which increased the likelihood of a causal relationship between suspected radioactive contamination near nuclear installations and excess childhood cancer cases.

The panel cited other investigations of cancer clusters near nuclear installations, including in Germany (Krümmel), in France (La Hague), in the United Kingdom (Sellafield) and in the US (Pilgrim plant, MA), which suggest that these clusters are radiogenic.

Its final conclusion was that:

Epidemiological causality criteria as applied to the data of the KiKK study do suggest a causal relationship between the emissions from nuclear power plants and the shown increases of childhood cancer cases with decreasing distance from these plants.

Although the KiKK researchers irrefutably established an association between frequency of excess cases of childhood malignancies and proximity to nuclear reactors, they rejected the possibility of a causal relationship between these cancers and radioactive emissions, and declared that their findings "remain unexplained". They did not question the population dose estimates provided by the operators of the nuclear plants, or the highly questionable radiation risk factors at those doses promulgated by radiation regulating bodies with strong ties to government and industry.

This study, which was meant to dispel public fears of detrimental health effects from emissions around nuclear power plants, actually corroborates a causal relationship. In the words of the independent scientific review commission:

"There exists no plausible alternative hypothesis."