

**Supplementary Comments**  
**on the**  
**Proposed Transport of Steam Generators**

**by Gordon Edwards, Ph.D., President,**  
**Canadian Coalition for Nuclear Responsibility**

**submitted to the**  
**Canadian Nuclear Safety Commission**

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## **Supplementary Comments: Proposed Transport of Steam Generators**

### **Public Trust**

The nuclear enterprise depends in large measure on the trust of the population, and the legitimacy of the regulatory agency depends on good governance. When a public agency is seen to be serving private interests rather than the public good, both trust and legitimacy are called into question.

If nuclear regulations are treated as merely suggestions that have no binding force, or that can be easily re-interpreted or dispensed with whenever it is convenient for the licensee to do so, then those regulations are seen as weak and the regulatory process itself is seen as lax.

The CNSC staff readily admits that the normal IAEA regulations cannot be satisfied by the proposed shipment of 16 steam generators from Bruce Power to Studsvik in Sweden, because there is no certified container and because the total amount of radioactivity in the 16 steam generators exceeds the maximum amount of radioactivity normally allowed in a single shipment by at least a factor of six. Thus a Special Arrangement is required if the shipment is to proceed.

According to the IAEA regulations, the licensing authority is not obliged to authorize a Special Arrangement for a radioactive shipment, but may do so if the situation warrants.

The concept of a Special Arrangement is based on the notion that if a certain shipment of radioactive materials must be carried out for some over-riding purpose, and the ordinary regulations cannot be met for some good reason, then a Special Arrangement may be made by the regulator in order to allow the shipment to go forward. But such a Special Arrangement is not obligatory; it is an extraordinary measure for special circumstances.

In the case of the Bruce A Steam Generators, CCNR believes that there is no over-riding purpose to be served by the shipment of the Steam Generators to Sweden, and therefore the CNSC should not grant permission for a Special Arrangement.

### ***Lack of Space?***

Bruce Power has already testified that the shipment is *not required due to a lack of storage space* at the WWMF -- in fact there is ample room to accommodate all the Bruce A Steam Generators -- and all the steam generators from the other OPG reactors as well, according to the OPG document *Reference Low and Intermediate Waste Inventory for the DGR* found at [http://www.nwmo.ca/uploads\\_managed/MediaFiles/539\\_ReferenceLowandIntermediateWasteInventoryfortheDGR.pdf](http://www.nwmo.ca/uploads_managed/MediaFiles/539_ReferenceLowandIntermediateWasteInventoryfortheDGR.pdf).

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### ***Financial Reasons?***

Bruce Power has also testified that the shipment is *not required for financial reasons* – at no time was any financial case made by Bruce Power, and in fact Duncan Hawthorn testified specifically during his testimony that money was not the primary consideration.

### ***Logistical Necessity?***

*There is no logistical reason* that necessitates the removal of the Steam Generators from the WWMF. The completions of the refurbishment of the Bruce A reactors and the return to service of those reactors in no way depends upon the removal of the steam generators from the property.

### ***Time Constraints?***

*There is no urgency* to address the ultimate disposition of the Steam Generators -- not in the next few months, years, or even decades. According to the 2006 Environmental Assessment, the Steam Generators are to be stored at the WWMF on the surface until 2043, and then segmented by OPG in preparation for long-term underground storage.

So on a practical level, there is no strong rationale to support the case that these steam generators have to be shipped halfway around the world in the near future.

Thus the shipment of 16 Steam Generators to Sweden, as proposed by Bruce Power, should not be given a transport licence by the CNSC. Why make a Special Arrangement to bypass standard transport regulations when there is no demonstrated need to make the shipment in the first place?

## **The Right Thing To Do?**

In fact the only rationale advanced by Bruce Power to justify the transport of the Steam Generators is that ‘‘It’s the right thing to do’’.

This is a remarkably flimsy and subjective rationale for sending radioactive wastes halfway around the world and back again, especially when there are hundreds of municipalities, non-governmental organizations and aboriginal communities on record as saying that it is not the right thing to do at all.

The CNSC should not be granting licences or authorizing Special Arrangements on the basis of highly debatable moral pronouncements by a profit-making private company or by any other licensee.

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So why is it “the right thing to do” according to Bruce Power? And why is CNSC staff so eager to insist that this proposal represents “best practice” in dealing with bulky radioactively contaminated equipment? More to the point, how is the public interest served by this proposal?

The public and the Commissioners have been told that the proposed shipment and consequent volume reduction will “reduce Bruce Power’s environmental footprint” by reducing the volume of wastes to be put in long-term storage.

But the environmental footprint associated with radioactive wastes is not based on mass or on volume. It is based on radioactivity. The proposed shipment does nothing whatsoever to reduce the radioactivity associated with the steam generators. Does it?

In theory, all of the radioactive material in the steam generators is to be returned to Bruce Power, in which case the environmental footprint is completely unaltered. It’s exactly the same long-term environmental burden in a different package. It may save Bruce Power a bit of money, by reducing OPG’s storage charges, but it doesn’t alter the environmental challenge associated with the radioactive waste itself, which still must be stored in perpetuity. So is this whole exercise just to save Bruce Power a bit of money?

In the real world, of course, we know not all of the radioactive material will be returned to Bruce Power; some of it will not be coming back at all. The environmental footprint will in fact be enlarged, not reduced. The environmental footprint will span an ocean.

Some of the radioactivity (such as the cesium isotopes) will be released as gases or vapours or radioactive dust (in the case of carbon-14) during the Studsvik process of disassembling, sand-blasting, crushing and melting the metal in the steam generators. Inevitably, some fraction of the radioactive contamination will find its way into the local Baltic environment. Some of it, no doubt, will end up in workers’ bodies. And some of it will end up in the scrap metal that is eventually to be sold on the open market as if it were normal, non-radioactive scrap metal. Indeed, it will be belnded with “clean” scrap metal to further diguise the fact that it contains man-made radioactive contaminants from the Bruce A nuclear power plants.

I guess we could all reduce our environmental footprint somewhat by taking our garbage cans around the neighbourhood and just discreetly dropping a bit here and a bit there, on other people’s driveways and sidewalks. By the time we got back home we would have achieved a slightly reduced environmental footprint, and everyone else would have an ever-so-slightly increased environmental footprint. Is this what CNSC staff cosniders “best practice” for radioactive wastes? Is this what the Commissioners regard as their public duty to facilitate?

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So some of the radioactive contamination from the Bruce Steam Generators will undoubtedly be staying in Sweden, and some will be exported around the world in countless metal products made from the "recycled" scrap metal, which is now radioactively contaminated. And how is this to be seen as a noble undertaking?

Bruce Power has failed to identify a single commercial retailer who would welcome or agree to purchase even mildly contaminated radioactive scrap metals.

The Steel Manufacturers' Association puts its position quite plainly:

Steel companies are confronted each day by the possible presence of radioactive materials in scrap. These materials are usually in the form of sealed radioactive sources, typically installed in measurement gauges used in manufacturing operations or in hospital equipment; scrap from decommissioned nuclear power and USDOE facilities; and imported scrap.

For the past 25 years the US Department of Energy (DOE) has maintained a policy of "free facilities across the country. Free release means that the material is cleaned, and if necessary, declassified, and then released into the stream of commerce for unrestricted use.

In the past, the amount of such material released was not significant. Following the end of the Cold War, DOE is decommissioning and dismantling several facilities across the nation, and expects to release thousands of tons of scrap metal from these facilities for recycling at steel companies without any dose-based clearance standards.

SMA members would be the primary intended recipients of this scrap and would stand to suffer serious economic injury, as much of this material is radioactively contaminated. SMA members are trying to keep radioactivity out of their mills, and therefore oppose free release.

For this reason, SMA members have not, and will not, accept scrap that is known to be radioactively contaminated.

Furthermore, the unrestricted release of radioactively contaminated metal from nuclear facilities for recycling would tarnish the image of recycling, and potentially lead consumers to avoid products made of steel – especially those with high recycled scrap steel content.

[http://www.ccnr.org/SMA\\_Radioactive\\_Scrap.pdf](http://www.ccnr.org/SMA_Radioactive_Scrap.pdf)

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Many organizations are deeply concerned about the growing contamination of the metal supply with man-made radioactive contaminants such as plutonium from the nuclear power industry and the nuclear weapons complex.

Does CNSC assume that what's good for Bruce Power is also good for the world? Does CNSC want to send out the message that radioactive waste is no longer intended to be sequestered from the environment or from articles of commerce?

If contaminated metal were to be recycled only within the nuclear industry, instead of being dumped onto unsuspecting consumers, some of the odiousness of this proposal would be mitigated. The transportation would still be an issue however.

*Perhaps there is a distinction to be made between NORM = Naturally Occurring Radioactive Materials and FORM = Fission-Origin Radioactive Materials. The former class of radioactive materials are ubiquitous in nature, usually in very small concentrations, and hence may be impossible to eliminate altogether in some recycled goods -- whereas the latter are man-made radioactive poisons that are being deliberately added as contaminants to otherwise "clean" materials. There is no justification for such a practice.*

### **Low Level Waste?**

Throughout this licence application, in public pronouncements and in formal testimony, both Bruce Power and the CNSC staff have insisted on describing the radioactive contents of the steam generators as "low-level radioactive wastes".

To an unsuspecting public, this terminology would seem to imply a very low inherent risk – a degree or type of radioactive contamination posing such a limited biological hazard that it would be foolish to even be concerned about it.

The fact of the matter is that these categories of radioactive materials have extremely simplistic definitions which do not reflect the toxicity or the longevity of the materials in question. To rely on such crude terminology in an attempt to foreclose public debate or allay public concern is tantamount to chicanery.

How many members of the public realize that the term "high-level radioactive waste" is reserved for irradiated nuclear fuel and nothing else? Thus no matter how intensely radioactive a pressure tube or a sealed source may be, any fool in the nuclear industry can glibly say, "Well, you know, that's not really high-level radioactive waste." This terminology may be useful within the industry, but the public is entitled to a more intelligent description of the radioactive material.

Indeed, the CCNR believes that such misleading terminology in connection with the steam generators does not serve the public interest at all, and is not compatible with the role of the CNSC as a protector of public health and safety. Why is there no discussion at all of the toxicity of these materials?

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It is worth noting that Studsvik, on its web site, describes the "tube bundle" inside a decommissioned steam generator as "highly radioactive". Without the outer shell of the steam generator as a shield, just how radioactive is the tube bundle? Does the CNSC staff know? Do the Commissioners know?

For in truth, Bruce Power is maintaining that the outer shell of the steam generator is the packaging, and the real radioactive cargo inside that packaging is the tube bundle. So – is the tube bundle also described as "low level radioactive waste"? Or not?

And if the tube bundle is in fact low level waste and therefore not worth worrying about, why doesn't Bruce Power just remove the tube bundle on site and send the (supposedly) non-radioactive shell for recycling? Why send all that radioactive junk across the ocean and back again if the shell is all that is wanted for recycling?

If Bruce Power doesn't know how to perform this operation (removing the tube bundle from the shell), it has several decades to learn. There is no hurry. And the gamma radiation will steadily diminish with time, making the job ever easier. And the hazards ever more trivial, if we are to believe Bruce Power's rhetoric.

### **Plutonium, Anyone?**

According to CNSC staff documents, approximately 90 percent of the mass of radioactive material inside the steam generators is plutonium. Indeed, two-thirds of the mass of radioactive material listed is plutonium-239, with another 24 percent of the mass made up of the four other isotopes of plutonium.

Plutonium is not a material to be handled carelessly or treated lightly. It is a very dangerous radioactive material with a very long hazardous lifetime. Neither Bruce Power nor the CNSC staff does itself any credit by trying to inculcate a contrary impression among the public.

For plutonium-239, the maximum permissible body burden for an atomic worker is 0.7 micrograms. According to Bruce Power's and CNSC staff's figures, there are about 36.8 grams of plutonium-239 inside the 16 steam generators (about two thirds of the total mass of radioactive materials). Simple arithmetic shows that this is enough, in principle, to give 52 million atomic workers their maximum permissible body burden of plutonium-239. This is hardly a trivial quantity.

Now in all honesty, how does it serve the public interest to describe this material as "the size of a tennis ball", as Bruce Power does (with the apparent blessing of the CNSC). Is such language meant to inform, or to trivialize? To enlighten, or to propagandize? To edify, or to mystify?

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Because of the toxicity of alpha-emitting materials such as radon, radium, polonium, and plutonium, the radioactive risks for such materials cannot be reduced to measurements of penetrating gamma radiation. Uranium tailings are hazardous for hundreds of thousands of years, mainly because of the alpha emitters. Irradiated fuel is hazardous even after thousands of years, mainly because of the alpha emitters.

Because the USA has had a nuclear weapons program for many decades, American nuclear authorities have come to realize that plutonium-contaminated wastes are not to be regarded or treated as low-level wastes. They have to be handled with almost as much care as high-level radioactive wastes.

If the density of the plutonium contamination is high enough, the plutonium-contaminated waste is classified as TRU waste and considered as a candidate material for a deep geologic repository. If the density is lower, the waste may still be classified as GTCC (Greater Than Class C) which requires unusually stringent measures for isolation from the environment over very long time periods.

It would be more accurate, and helpful, to define the radioactive contamination inside the steam generators as primarily plutonium, with a number of other radioactive materials mixed in. Such a description is more useful than the "low level radioactive waste" epithet.

### **No Danger?**

Last year, over 200 workers inhaled a fine plutonium dust in the workplace because they were told by Bruce Power that there was no risk, and therefore no need to wear protective equipment. In that exposure incident, which went undetected for weeks, the Bruce Power representatives revealed a remarkable degree of ignorance and irresponsibility, and now over 200 men have come away with a small body burden of plutonium which will remain with them for years.

Yet to the best of our knowledge, there has been no fine or penalty assessed by the CNSC against Bruce Power, nor was anyone at Bruce Power fired or demoted, or relieved of duty, nor was there any determination of criminal negligence or dereliction of duty at the higher levels of the CNSC or Bruce Power.

The only ones who suffered any ill consequences were the workers, and their only mistake lay in trusting the CNSC and Bruce Power to tell them the truth and to provide them with a safe workplace environment. Yet most of those workers had never even been informed of the existence of alpha radiation, let alone the extraordinary dangers of internal alpha contamination. Those in charge of the workers were, apparently, completely unaware of the dangers of plutonium in the piping.

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Does anyone assume responsibility here? Is anyone held accountable?

Now Duncan Hawthorn has assured us (during the September public hearing) that Bruce Power is fully and completely aware of the radioactive inventory inside the steam generators (even if it occasionally leaves out an isotope or two) – and by its own published figures, that radioactive inventory is 90 percent plutonium.

So let's see now – how exactly did the plutonium get into the steam generators unless it passed through the pipes leading from the core of the reactor to the steam generator? And if that is the case, then how can Bruce Power claim that it did not know there was plutonium in the feeder pipes at the time of the tragic and unnecessary exposure of 200 men to inhaled plutonium dust?

During the public hearings on September 28-29, 2010, Duncan Hawthorn was asked by one of the Commissioners about an open letter sent out by Dr. Frank Greening, dated February 17, 2010, advising Bruce Power, and anyone else who would listen, of the presence of plutonium contamination in the "feeder pipes, pressure tubes, and steam generator components". That letter by Dr. Greening formed a part of our CCNR submission, submitted on September 13, 2010.

In his recorded testimony at the CNSC hearing, Mr. Hawthorn misrepresented the contents of Dr. Greening's letter shamelessly, and nobody on the CNSC staff did anything to set the record straight. Mr. Hawthorn implied that Dr. Greening was simply musing in retrospect, after the plutonium-contamination event had happened, that there might have been some reason to suspect the presence of plutonium in the pipes if only anyone had thought about it ahead of time.

But that's not what Dr. Greening was saying, and Mr. Hawthorn – who is so fond of insisting on dealing with "the facts" – knows that that is not what Dr. Greening was saying. Moreover, the CNSC staff should also know perfectly well that that is not what Dr. Greening was saying.

Here is what Dr. Greening actually wrote:

I trust that Bruce Power is not claiming that such feeder pipe contamination was unexpected because OPG and AECL have been well aware of this issue for many years and it's not long ago that Bruce Power nuclear reactors were operated by OPG.

I discovered alpha contamination on Pickering feeder pipe and pressure tube samples many times during my 23 -year career at OPG. Thus, in the early 1980s I reported surface concentrations of Pu-238, Pu-239, Am-241, Cm-242 and Cm-244 (in the nCi/mg range) in the oxide scale on several

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Pickering Unit 2 inlet feeder pipes -- see Ontario Hydro Research Division Report 84-262-K issued August 13, 1984.

I request that this information be passed on to the CNSC staff who are looking into this incident and ask them to please ensure that health physicists at Bruce Power are made aware of the level of alpha contamination that is to be expected on feeder pipes, pressure tubes and steam generator components removed from CANDU reactors here in Canada.

The incompetence and dishonesty displayed by both Bruce Power and CNSC staff in covering up the possibly criminal negligence on the part of certain individuals at Bruce Power in the context of the plutonium contamination of over 200 workers last year is shocking.

And the willingness on the part of CNSC staff to allow the transcript of CNSC public hearings to be contaminated with distortions and untruths from a licensee without any effort to set the record straight is also shocking.

These are among the reasons why CCNR has no confidence in the assurances given by Bruce Power and CNSC staff that there is "no danger" in the shipment of 16 plutonium-laden steam generators through the Great Lakes and St. Lawrence River en route to Sweden.

We do not believe that Bruce Power or CNSC staff has any accurate knowledge of the radioactive inventory of the steam generators. We believe that there is an enormous amount of guesswork involved, based on clever but highly questionable methodologies. We believe that the data base is extremely limited given the lack of homogeneity of the radioactive contamination, the small number of pipes that were studied, and the impossibility of measuring all of the radioactive species.

We do not believe that Bruce Power or CNSC staff has any accurate knowledge of how much of the internal contamination is 'fixed' and how much is 'loose'.

These steam generators have been dry and corroded for a long time now, and much of the contamination that may have been fixed originally could have easily flaked off and become loose, especially due to the rotation, manipulation and transportation of the steam generators. If plutonium dust can escape from feeder pipes to contaminate the lungs of 200 workers, why should we believe that such is not also the case with the plutonium contamination in the steam generators?

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### **Who Owns the Waste?**

CCNR has discovered that up until October of last year, the steam generators were owned by Ontario Power Generation (OPG) which is a crown corporation wholly owned by the Government of Ontario.

The following excerpts from a letter from OPG to the Ontario Energy Board confirms the fact that, some time in October 2009, OPG transferred "title and possession" of the steam generators to Bruce Power so that BP could proceed with the proposed shipment to Sweden:

November 3, 2009.

VIA EMAIL

Ms. Kristen Walli  
Board Secretary  
Ontario Energy Board  
P.O. Box 2319  
2300 Yonge Street, Suite 2700  
Toronto, ON M4P 1E4

Dear Ms. Walli:

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STATUS REPORT TO THE ONTARIO ENERGY BOARD  
Agreements pursuant to the Bruce Lease Transaction

Date of Report: November 3, 2009

Changes from October 1, 2009 to October 31, 2009

Category 2 – Amended Agreements (includes amendments, replacements or extensions)

The Amending Agreement provides for the return of possession and title of waste Bruce A Unit 1 & 2 Steam Generators (SGs) from OPG to Bruce Power. The SGs are currently in OPG storage, and Bruce Power will prepare and ship them to Sweden for volume reduction and processing. Residual radioactive waste will be shipped back to Canada to be stored by OPG as low/intermediate level radioactive waste. OPG will refund to Bruce Power funds previously received to process the waste SGs for disposal in exchange for the refund. OPG will be discharged of its obligation to Bruce Power for future processing and disposal of waste SGs.

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This discovery raises a number of interesting questions.

First of all, why is OPG not a party to this proposal of Bruce Power's, since OPG is the ultimate owner of all the radioactive waste that is produced by the Bruce Reactors?

Secondly, why is it not OPG rather than Bruce Power that is applying for this licence on its own behalf? In other words, why is this proposed shipment a BP initiative and not an OPG initiative?

Thirdly, why is OPG not at the very least a participant in the CNSC licensing process, by submitting written testimony or by sending an OPG representative to the September hearing in order to document and to answer questions about the role of OPG in all of this?

Fourthly, according to the existing licence that OPG has from the CNSC for operating the Western Waste Management Facility (WWMF, where the steam generators are currently stored), would OPG be prohibited from exporting the steam generators to Sweden?

Fifthly, if OPG is in fact not permitted under its CNSC licence to export radioactive wastes from WWMF to other jurisdictions, then how is it permissible for Bruce Power to be enabled by OPG to do what OPG is forbidden to do?

Sixth, would the Commissioners be concerned to learn that a licence requirement is being circumvented by using a third party to assume temporary ownership and responsibility for that express purpose?

There is a degree of speculation in these questions to be sure. CCNR is not certain that OPG is forbidden to import or export radioactive waste from the WWMF, although that is our belief. Some years ago, when Hydro Quebec stated that it would be sending its refurbishment wastes (from Gentilly-2) to Ontario's WWMF, CCNR and other groups challenged that assumption, and Hydro Quebec recanted. We were informed at that time that WWMF did not have the authority to import radioactive wastes from another province.

Here is an excerpt from a 2006 CNSC transcript which seems to confirm this:

<http://www.suretenucleaire.gc.ca/eng/commission/pdf/2006-03-17-Decision-OPG-WWMF-e.pdf>

Paragraph 59. CNSC staff noted that the OPG's **WWMF** operating licence does not permit the import or export of materials or prescribed equipment.

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### **Conclusion**

Given the level of public concern over the proposed steam generator shipment,

Given that during the 2006 EA both Bruce Power and CNSC staff indicated that the steam generators were radioactive wastes that could not and would not be recycled,

Given that public trust in the Environmental Assessment process must be maintained and strengthened if CNSC is to enjoy public confidence when it plays a key role in carrying out such Environmental Assessments in future,

Given that the follow-up period for the 2006 EA into the refurbishment of the Bruce A Reactor Units 1 and 2 does not expire until December 31 2010,

Given that the levels of plutonium contamination inside the steam generators are unusually high,

Given that there is no consensus as to what is "the right thing to do",

Given that national and international organizations have expressed opposition to the free release of metals contaminated with Fission-Origin Radioactive Materials,

Given that there is no logistical necessity for the transport of the steam generators,

Given that a transport licence would require a Special Arrangement to disregard certain IAEA regulations regarding the transport of radioactive materials,

Given that the IAEA requirement for a maximum amount of radioactivity of  $10A_2$  for inland water craft and  $100 A_2$  for marine craft is based, at least in part, on the importance of drinking water sources and other usages of inland waterways,

Given that the radioactive inventory could be underestimated by as much as a factor of 2 or 3, or even by an order of magnitude,

Given that the fraction of radioactive contamination that is fixed and the fraction that is loose is not known with any certainty,

Given the precedent that would be established by authorizing the transport of radioactive reactor wastes through the Great Lakes and the St. Lawrence River,

Given the uncertainty regarding the roles of OPG and Bruce Power in exporting radioactive waste from the WWMF,

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Given the likelihood that technology for carrying out all necessary volume reductions on site will be developed in the coming decades,

The Canadian Coalition for Nuclear Responsibility urges the Commissioners of the CNSC

- not to issue a transport licence for the 16 steam generators on the grounds that there is no proven necessity for the shipment and therefore no legitimate rationale for a Special Arrangement; or
- to recommend to the Minister that either a new Environmental Assessment be initiated into the generic question of what policies Canada should have regarding the transport, import, export, and recycling of radioactively contaminated equipment and other radioactive reactor wastes (other than irradiated nuclear fuel), or
- that the previous 2006 EA be reopened (in fact it is not yet terminated since it is still in the follow-up period) to take into account that the original refurbishment project has been altered in such a way as to potentially affect or concern millions of off-site people as to potential environmental consequences, whereas the original project, as originally detailed, did not elicit such concerns.

Thank you for the opportunity to submit these supplementary comments.

Gordon Edwards, Ph.D., President,  
Canadian Coalition for Nuclear Responsibility.

## **Plutonium in the Bruce “A” nuclear steam generators**

Here is a partial list of radioactive contaminants inside a single used steam generator from each one of the two reactors (Units 1 and 2 of Bruce A), according to CNSC (document CMD-10-H19B). The mass (in grams) of each of the radioactive materials listed is estimated by CNSC staff.

<b>RADIONUCLIDE</b>		<b>MASS</b>	
Name of Isotope (with Atomic Mass)	Half-Life (years)	Unit 1 (grams radioactive material)	Unit 2 (grams radioactive material)
Americium-241	430 y	0.103412	0.102412
Americium-243	7 400 y	0.002162	0.002432
Carbon-14	5 700 y	0.009065	0.072501
Curium-244	18 y	0.002644	0/000347
Cobalt-60	5.3 y	0.001781	0/000881
Cesium-137	30 y	0/000249	0.000238
Europium-154	8.8 y	0.000027	0.000290
Iron-55	2.7 y	0.000272	0.000290
Hydrogen-3 (Tritium)	13.0 y	0.000057	0.000051
Hafnium-181	2.7 y	0.000001	0.000001
Iodine-129	17 000 000 y	0.000060	0.000060
Niobium-94	20 000 y	0.002159	0.002158
Nickel-59	75 000 y	0.173601	0.036723
Nickel-63	96 y	0.030194	0.006526
Neptunium-237	2 100 000 y	0.028703	0.033295
<i>Plutonium-238</i>	<i>88 y</i>	<i>0.007507</i>	<i>0.004703</i>
<i>Plutonium-239</i>	<i>24 000 y</i>	<i>2.124977</i>	<i>2.471769</i>
<i>Plutonium-240</i>	<i>6 500 y</i>	<i>0.827304</i>	<i>0.957105</i>
<i>Plutonium-241</i>	<i>14 y</i>	<i>0.021309</i>	<i>0.030809</i>
<i>Plutonium-242</i>	<i>380 000 y</i>	<i>0.048762</i>	<i>0.056317</i>
Antimony-125	2.8 y	0.000001	0.000001
Strontium-90	29 y	0.009097	0.007581
Technetium-99	210 000 y	0.000143	0.000092
<b>TOTALS</b>			
<b>Long-lived (&gt; one year half-life)</b>		<b>3.416108</b>	<b>3.787315</b>
<b>Mass of plutonium isotopes only</b>		<b>3.029859</b>	<b>3.520703</b>
<b>Percent plutonium</b>		<b>88.7%</b>	<b>93.0%</b>
<b>TOTAL MASS</b>			

*(Source: CNSC)*

*There are 5 plutonium isotopes present in the steam generators.  
In addition there are 18 other long-lived isotopes listed.*

In the 16 Bruce A steam generators (8 from Unit 1 and 8 from Unit 2), the total mass of radioactive material is estimated to be about 57.6 grams, of which 52.4 grams is plutonium. So plutonium makes up 91.0 percent of the mass of radioactive material in the steam generators.

Plutonium is extremely dangerous even in minute quantities. The maximum permissible “body burden” of plutonium-239 for an atomic worker (for instance, someone working in the nuclear weapons industry) is 0.7 micrograms. Inside the steam generators there are 36.8 grams of this one particular isotope – enough, in principle, to give over 52 million atomic workers their maximum permissible body burden of plutonium-239. If we include all five isotopes of plutonium, the number of atomic workers who could be overdosed, in principle, is just about doubled.

Plutonium isotopes also have very long half-lives, ranging from decades to hundreds of thousands of years. This means that any accident which resulted in a spill could pose long-lasting dangers.