Comments on

Consideration of Environmental Impacts on Temporary Storage of Spent Fuel After Cessation of Reactor Operation

Docket ID No. NRC-2012-0246:

submitted by the

Canadian Coalition for Nuclear Responsibility

to the

US Nuclear Regulatory Commission

"The inadequacy of NRC's Proposed Ruling on the storage of irradiated nuclear fuel"

by

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The Canadian Coalition for Nuclear Responsibility

The Canadian Coalition for Nuclear Responsibility (CCNR) – also known as Le Regroupement pour la surveillance du nucléaire (RSN) – is a non-profit pan-Canadian organization based in Montreal, Quebec.

Founded in 1975, CCNR is dedicated to education and research on all issues related to nuclear energy, whether civilian or military – including non-nuclear alternatives – especially those pertaining to Canada.

CCNR has intervened in environmental assessment hearings and provided testimony at public inquiries in every province and territory of Canada, and CCNR researchers have given expert testimony in courts of law in both Canada and the USA.

CCNR has disseminated technical information in laymen's language on such topics as uranium mining, reactor safety, radioactive waste management, proliferation of nuclear weapons, health effects of atomic radiation, and non-nuclear energy strategies.

CCNR regularly provides information on nuclear issues, as requested, to journalists, researchers, communities and decision makers.

In Quebec, CCNR has been a major player on nuclear issues for almost forty years. Here are a few highlights of CCNR activities in the province:

- CCNR submitted a substantial position paper on nuclear power and alternative energy to the government of René Lévesque, two years before the government declared a moratorium on any new nuclear reactors in Quebec;
- CCNR provided speakers for a series of public meetings in the Eastern Townships and Vermont opposing the US DOE proposal to locate a high-level nuclear waste repository in the Northeast USA, culminating in Premier Bourassa's declaration that Quebec will never allow a permanent nuclear repository on Quebec territory or on its borders;
- CCNR provided educational materials related to a district-heating nuclear reactor to be donated by AECL to the CHUS (Centre Hospitalier de l'Université de Sherbrooke), resulting in a unanimous decision by the CHUS' Board of Directors to reject AECL's offer;
- CCNR participated in the Public Debate on Energy held under the auspices of the Quebec government, leading to the creation of the Régie de l'Énergie.
- CCNR intervened in two separate Environmental Assessment (BAPE Hearings on nuclear waste storage faculties at Gentilly, leading to a recommendation that the government of Quebec establish a clear policy for the long-term management of radioactive wastes;

Gordon Edwards ~ Biographical Notes

Gordon Edwards graduated from the University of Toronto with a Gold Medal in Mathematics and Physics (1961). He earned Master's degrees in Mathematics and English Literature at the University of Chicago (1962-64) under a Woodrow Wilson Fellowship. After teaching at the University of Western Ontario for 4 years, he obtained a Ph.D. in Pure Mathematics from Queen's University (1972).

In 1970 he became the editor of ***Survival***, an environmental newsletter with subscribers in 13 countries. In 1973 he coordinated a 7-volume study of the Role of Mathematics in Canadian Business, Government, Education and Research for the Science Council of Canada. In 1974 he joined the Faculty of Vanier College where taught until 2010

In 1975 he co-founded the Canadian Coalition for Nuclear Responsibility (CCNR) and rose to prominence as one of Canada's best-known independent experts on nuclear technology, uranium, and weapons proliferation. He created the CCNR website: www.ccnr.org.

Dr. Edwards first became involved in uranium mining during the Cluff Lake Board of Inquiry into Uranium Mining in Saskatchewan in 1977, where he cross-examined industry and government witnesses on a daily basis for three weeks. In 1978, Dr. Edwards produced a groundbreaking analysis showing that the cancer risk from radon gas is much higher than Canadian authorities claimed. His work was confirmed by the BC Medical Association and by experts hired by the Atomic Energy Control Board.

Dr. Edwards became involved in reactor safety and radioactive waste issues during the Ontario Royal Commission on Electric Power Planning in 1977-78, where he was retained to cross-examine industry witness on a daily basis for three months in addition to providing his own independent testimony. In its Report on Nuclear Power in Ontario, entitled "A Race Against Time", the Commission concluded that Dr. Edwards' estimates of meltdown probabilities were more credible than those put forward by the nuclear industry. In 1979 and 1980, Dr. Edwards was a major invited witness at 15 weeks of public hearings on reactor safety and nuclear waste management conducted by the Select Committee on Ontario Hydro Affairs, an all-party committee of the Ontario Legislature.

For over 35 years Dr. Edwards has acted as a consultant to many governmental and non-governmental organizations, including the Auditor General of Canada, the Ontario Royal Commission on Electric Power Planning, the Select Committee on Ontario Hydro Affairs, United Steelworkers of Canada, Siting Task Force for Radioactive Wastes, and others. He has performed educational and analytical work for aboriginal organizations, including Inuit Tapiriit Kanatami, Assembly of First Nations, Canadian Congress of Aboriginal Peoples, Mohawks of Kanesetake, Chippewas of Nawash, the Sahtu-Dene, and the Cree of Eeyou-Istchee (Northern Quebec).

Dr. Edwards was awarded the 2006 Nuclear-Free Future Award in the Education Category. He has also been awarded the Roslie Bertell lifetime achievement award and the 2013 YMCA Peacemaker's Award. He is often interviewed on nuclear matters by radio and television journalists and has given keynote addresses at International Conferences in Stockholm, Madrid, Hong Kong, Salzburg, Toronto, Ottawa, and Huron Ohio.

Summary of Conclusions:

CCNR finds the DGEIS inadequate as a basis for rulemaking.

Conclusion 1.

The Canadian Coalition for Nuclear Responsibility (CCNR) finds that it is imprudent for NRC to base its entire analysis on the assumption that a geologic repository will become available within a few decades. To provide a thorough analysis of potential environmental impacts of spent fuel storage, NRC needs to analyze the consequences of an indeterminate delay in the availability of such a geologic repository, as well as the implications of such a repository never becoming available. Anything less than that would be tantamount to basing policy decisions on wishful thinking.

Conclusion 2.

CCNR considers it irresponsible for NRC to assume that any method exists or will exist for the safe permanent disposal of irradiated nuclear fuel without a precise and verifiable scientific definition of the word "disposal" – complete with detailed scientific criteria for determining when "safe permanent disposal" has been accomplished, and accompanying methodologies for verifying whether those criteria have or have not been met. Any other approach amounts to drawing the target after the dart has been thrown.

Conclusion 3.

CCNR recommends that NRC elaborate a set of rules and policies predicated on the possibility that no safe permanent solution to the problem of high-level nuclear waste will be demonstrated and/or available in the foreseeable future. In particular, CCNR urges the NRC to rule that high-level nuclear waste must not be subject to abandonment under any circumstances, but must be fully retrievable and subject to continual monitoring at all times, until such time as a scientifically verifiable safe permanent solution to the nuclear waste problem has been demonstrated beyond doubt.

Conclusion 4.

CCNR recommends that NRC elaborate a set of rules and policies related to the concept of Rolling Stewardship as applied to the intergenerational management of irradiated nuclear fuel, including detailed mechanisms for transferring responsibility for managing the wastes from one generation to the next, mechanisms for funding the long-term management of the waste including monitoring, retrieval, recharacterization and repackaging of the waste and reinstructing each successive generation.

Conclusion 5.

CCNR finds that NRC assurances of the safety of temporary storage measures for spent nuclear fuel under both wet and dry storage regimes are not supported by adequate analysis of the consequences of using high burn-up fuel in commercial reactors. CCNR recommends that NRC refrain from all licensing decisions that may add to the inventory of high burn-up fuel in temporary storage pending the outcome of a public review process based on a thorough analysis of all safety implications of high burn-up fuel vis-à-vis such things as accelerated cladding degradation, added criticality potential, obstacles to safe transport of spent fuel, deterioration of spent fuel handling equipment, alterations in isotopic composition (source terms), as well as increased radioactivity and heat generation in any geologic repository or surface facility.

CCNR recommends that the current suspension of licensing decisions by the NRC be continued indefinitely until the NRC has established detailed plans for the long term management of irradiated nuclear fuel that is not based on the unwarranted assumption that a safe permanent walk-away disposal method will become available within a few decades.

Introduction

> ***The proposed rule would amend the Commission's regulations by revising its generic determinations on the timing of the availability of a geologic repository for commercial high-level radioactive waste and spent nuclear fuel, and on the environmental impacts of storage of spent fuel at or away from reactor sites after the expiration of reactor operating licensing.***
>
> *US NRC Summary,*
> *http://www.regulations.gov/#!docketDetail;D=NRC-2012-0246*

The U.S. Nuclear Regulatory Commission (NRC) has failed to address adequately the scope of the ultimate environmental, political and economic challenges associated with the continued production and accumulation of long-lived radiotoxic waste materials, absent a well-planned and scientifically based strategy for the long-term management of these wastes over a period of time that dwarfs the span of human history. In particular, it is imprudent for NRC to presume that a geologic repository will become available within a few decades.

The NRC has also failed to address in an adequate manner the environmental risks associated with continuing the current management practices of wet storage in spent fuel pools and dry storage in canisters, particularly in light of the unexamined implications of NRC's decision to allow licensees to use high burn-up nuclear fuel which adds significantly to the fission product inventory and heat loadings associated with the resulting irradiated fuel, thereby invalidating analyses that were carried out years ago based on lower burn-up.

For these reasons, the DGEIS is unacceptable as a basis for Rulemaking.

1. The Lack of a Safe Permanent Disposal Method

1.1. A History of Failure

The NRC continues to assume that a geologic repository for the safe permanent disposal of irradiated nuclear fuel from power reactors (whether in the form of fuel assemblies or as solidified post-reprocessing waste) will become available within a few decades. There are good reasons to distrust that assumption.

According to the California Energy Resources and Conservation Commission's 1977 Report on the concept of geologic disposal of nuclear waste, the USA had (up until that time) attempted on seven different occasions to locate an underground repository for the safe long-term disposal of high-level nuclear waste, and failed all seven times.

The first such attempt was in an abandoned Salt Mine in Lyons, Kansas; in 1957 Milt Shaw of the AEC went to the US Congress to request funding for the immediate disposal of spent nuclear fuel in the mine, which he testified was the best site in the USA for such a purpose based on 15 years of research. Within months the site was shown to be completely unsuitable for hydrogeological reasons. Milt Shaw was fired.

The extensive series of California Hearings into the concept of geologic disposal of irradiated nuclear fuel was mandated by the California Legislature and administered by Commissioner Emilio Varanini, who authored the final report. After the report was released, he was quoted as follows:

> **If everything worked perfectly as far as they are concerned, if every one of their ideas were correct, and we were able to proceed on a timely basis, waste disposal will not be demonstrated . . . until sometime around 1987. *We, however, have a more fundamental problem. We think it probable that it will never be demonstrated.***
>
> **Excessive optimism about the potential for safe disposal of nuclear wastes has caused backers of nuclear power to ignore scientific evidence pointing to its pitfalls. That's the real crux of what we found -- that *you have to weigh scientific evidence against essentially engineering euphoria*.**
>
> *Commissioner Emilio Varanini, quoted in*
> *The San Francisco Chronicle, January 12, 1978*

Since the California Commission Report there have been at least two additional failed attempts to locate a geologic repository – one in the Northeast and one in the Southwest (the Yucca Mountain project). There is still, to this day, not a single example of an operational repository for the "disposal" of irradiated nuclear fuel anywhere in the world.

Conclusion 1.

The Canadian Coalition for Nuclear Responsibility (CCNR) finds that it is imprudent for NRC to base its entire analysis on the assumption that a geologic repository will become available within a few decades. To provide a thorough analysis of potential environmental impacts of spent fuel storage, NRC needs to analyze the consequences of an indeterminate delay in the availability of such a geologic repository, as well as the implications of such a repository never becoming available. Anything less than that would be tantamount to basing policy decisions on wishful thinking.

1.2. A Questionable Concept

The challenge of permanently disposing of indestructible or very long-lived toxic materials is an unsolved problem of the human race. As Nobel Prize-winning physicist Hannes Alfven has said in reference to nuclear power, “You cannot claim that a problem is solved simply by pointing to all the efforts that have been made to solve it.”

The safe permanent disposal of nuclear waste is a dubious concept with no precise scientific meaning. In other words, there are no measurable or scientifically verifiable criteria that will determine whether “safe permanent disposal” has or has not been accomplished. No matter how much scientific effort goes into the preparatory work, or into the post-closure assessment, science has no way of guaranteeing that the containment will not subsequently fail over hundreds of thousands or even millions of years.

To dispose of something permanently is to get rid of it “once and for all”, but we do not know how to get rid of irradiated nuclear fuel. We only know how to repackage it and relocate it. No doubt we can relocate it to a geologic repository excavated for that purpose, but there is no scientific principle that allows us to determine whether or not it will stay where we put it. Geology is not a predictive science, and human intervention cannot be excluded.

Science has confirmed that some geological formations have remained stable for hundreds of millions or even billions of years. But it is impossible to emplace irradiated nuclear fuel in an undisturbed geological formation without first disturbing it. And there is no technology available to restore a disturbed geological formation to its original integrity.

Moreover the nuclear wastes themselves are not inert, but active – thermally active, chemically active, and radioactive. Even the possibility of accidental criticality in the underground repository cannot be completely ruled out. Once these active materials have been emplaced in an excavated cavity where the surrounding geological stress field has been permanently disrupted, these nuclear wastes will embark upon a history all their own – unobserved and uncontrolled by human society. Science is ill-equipped to predict the long-term behavior of such extraordinary materials in a man-made repository under such unprecedented conditions. In fact there are no scientific principles that allow us to test whether or not such predictions are even in the right ball-park when extended over periods of hundreds of thousands of years. Current mathematical knowledge is inadequate to provide bounding estimates for the accumulated computational errors arising from billions of iterative calculations, which can in some unusual circumstances be larger than the numerical answers themselves.

The mathematical models required to carry out such calculations are, on the one hand, extremely simplified descriptions of the complex evolution of the underground environment, and on the other hand, they are impossible to verify over the extraordinarily long time periods involved. All programs need debugging – witness the recent embarrassing glitches associated with the rollout of Obamacare, which were fortunately fixed in a rather short time frame. But we do not have the ability to wait for tens or hundreds of millennia to see if the predictions of our mathematical models correspond to the actual long-term behavior of the nuclear wastes within a geologic repository, so we are ultimately basing assurances of safety on the unverified hypotheses that are embodied in the mathematical programs. This is a sophisticated form of wishful thinking – a technological "Hail Mary".

All this would not matter so much if it weren't for the fact that the waste byproducts in irradiated nuclear fuel remain so highly radiotoxic even after a million years of storage. In a 1978 paper published by the US Geological Survey, Circular 779, entitled "Geologic Disposal of High-Level Radioactive Wastes – an Earth-Science Perspective", the authors point out that even after a million years of storage, the radiotoxicity of the then-projected inventory of irradiated nuclear fuel from US power plants is extraordinarily high. As a hypothetical measuring mechanism, the authors point out that all of the water in the Great Lakes basin would be required to dilute the radioactive contents of the irradiated nuclear fuel to the maximum level of radioactive contamination that is legally allowed for drinking water. Of course we all understand that this hypothetical scenario is not going to happen, but it is a reminder that even 99.99 percent perfect containment of this material is just not good enough.

Conclusion 2.

CCNR considers it irresponsible for NRC to assume that any method exists or will exist for the safe permanent disposal of irradiated nuclear fuel without a precise and verifiable scientific definition of the word "disposal" – complete with detailed scientific criteria for determining when "safe permanent disposal" has been accom-plished, and accompanying methodologies for verifying whether those criteria have or have not been met. Any other approach amounts to drawing the target after the dart has been thrown.

1.3. A Conflict of Interest

From the earliest days of nuclear power, nuclear proponents have asserted with the utmost confidence that the safe permanent disposal of nuclear waste is not a technical problem, but a public relations problem. The assertion is partly true, at least from the point of view of the nuclear industry, as failure to find a solution to the nuclear waste problem is a major environmental, political and economic obstacle to the expansion of the industry, and is therefore a threat to the continued existence of nuclear power as a commercial energy source.

Nuclear proponents feel the need to reassure decision-makers and the public that nuclear waste is not an insuperable problem, because otherwise their industry has no future. This creates a conflict of interest that has clouded the judgment of nuclear proponents and led them to make a number of exaggerated and unsupportable claims that are not scientifically verifiable. Law-makers have been misled into enacting legislation obligating the federal government to "dispose" of the industry's irradiated nuclear fuel, based on false assurances from the industry that the disposal problem had been solved, when in fact it had not been solved and is still not solved. Decision makers have placed their trust in nuclear proponents who have been more concerned with meeting the public relations needs of the industry than the long-term safety concerns associated with the ever-growing inventories of highly radiotoxic and indestructible waste byproducts. The NRC should not allow itself to be a party to this deception.

For the NRC has also fallen under the spell of accepting this unverifiable assumption that a safe permanent disposal method exists in the form of a deep underground geologic repository, as if it were a scientifically demonstrated fact.

This assumption has distorted the NRC rulemaking function to such an extent that in 2012 a court of law has ordered NRC to review its rules regarding the storage of irradiated nuclear fuel, specifically challenging the NRC notion that a safe permanent disposal method in the form of a geologic repository will become available in the next few decades. In its current efforts to meet the court's challenge, NRC has failed to consider that the industry's fundamental assumption that a solution to the waste problem exists may be incorrect, and to elaborate a set of policies based on that possibility.

The NRC's job is to protect the public health and safety and to protect the environment over the long term. To carry out its responsibilities NRC must rely on sound science and devolop prudent policies for the future, undeterred by the industry's perceived public relations needs.

Conclusion 3.

CCNR recommends that NRC elaborate a set of rules and policies predicated on the possibility that no safe permanent solution to the problem of high-level nuclear waste will be demonstrated and/or available in the foreseeable future. In particular, CCNR urges the NRC to rule that high-level nuclear waste must not be subject to abandonment under any circumstances, but must be fully retrievable and subject to continual monitoring at all times, until such time as a scientifically verifiable safe permanent solution to the nuclear waste problem has been demonstrated beyond doubt.

1.4. "Rolling Stewardship"

In the absence of a safe permanent one-shot solution to the challenge of keeping nuclear waste out of the environment of living things for the indefinite future, the only responsible course of action is to adopt a policy of "Rolling Stewardship".

We do know how to package nuclear waste and store it in a safe manner for decades at a time. Rolling stewardship is an intergenerational management concept. It requires monitoring and maintenance of the waste for an indefinite period of time, with responsibility being passed on from one generation to the next, including episodes of retrieval, recharacterization and repackaging of the waste. It also requires a mechanism for reinstructing the next generation, providing detailed information on the nature of the wastes and the associated hazards, and ensuring that the next generation is fully aware of the need to spend time and money on the wastes and to see that corrective action is taken on a timely basis if need be.

For more on Rolling Stewardship see Appendices I and II. These documents were produced in relation to a proposal by Ontario Power Generation (OPG) to construct a Deep Geological repository (DGR) less than a mile from Lake Huron to store all nuclear waste from Ontario's 22 nuclear power reactors except for the irradiated nuclear fuel. The proposal is based on the presumption that the waste will eventually be abandoned – even though many radionuclides involved will remain dangerously radiotoxic for hundreds of thousands of years – thereby turning the DGR into a DUD – a Deep Underground Dump. CCNR believes abandonment of these wastes is both unethical and unscientific.

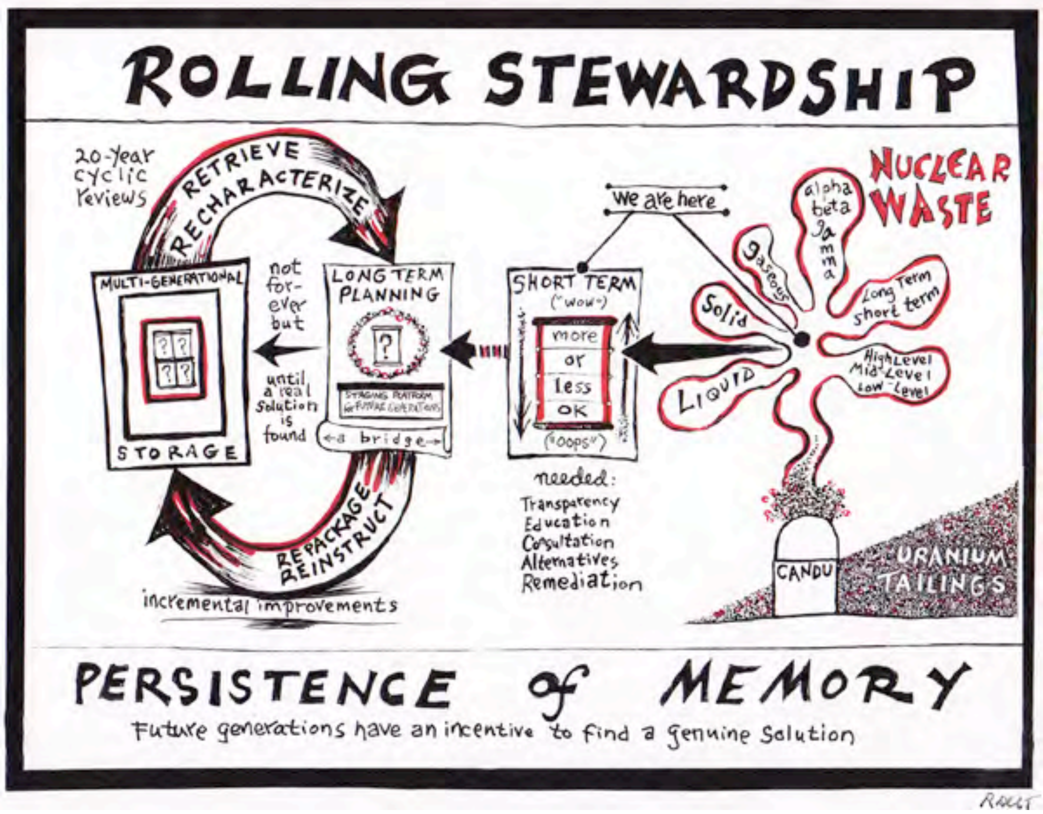
Although the OPG proposal is not directly relevant to the storage of irradiated nuclear fuel, the principles of Rolling Stewardship are essentially the same in either case. In fact many of the radionuclides found in irradiated nuclear fuel are also present in smaller concentrations in the low-level and intermediate-level reactor wastes, including those related to the retubing, steam generator replacement, and final radioactive demolition of the reactors themselves.

Appendix I is a slightly edited version of the transcript of oral testimony to the Joint Review Panel examining the OPG proposal, given by Gordon Edwards on behalf of CCNR on August 20, 2013. Appendix II is a supplementary document prepared for the Panel, at their request, written by Gordon Edwards and Robert Del Tredici, providing further documentation on the subject of Rolling Stewardship.

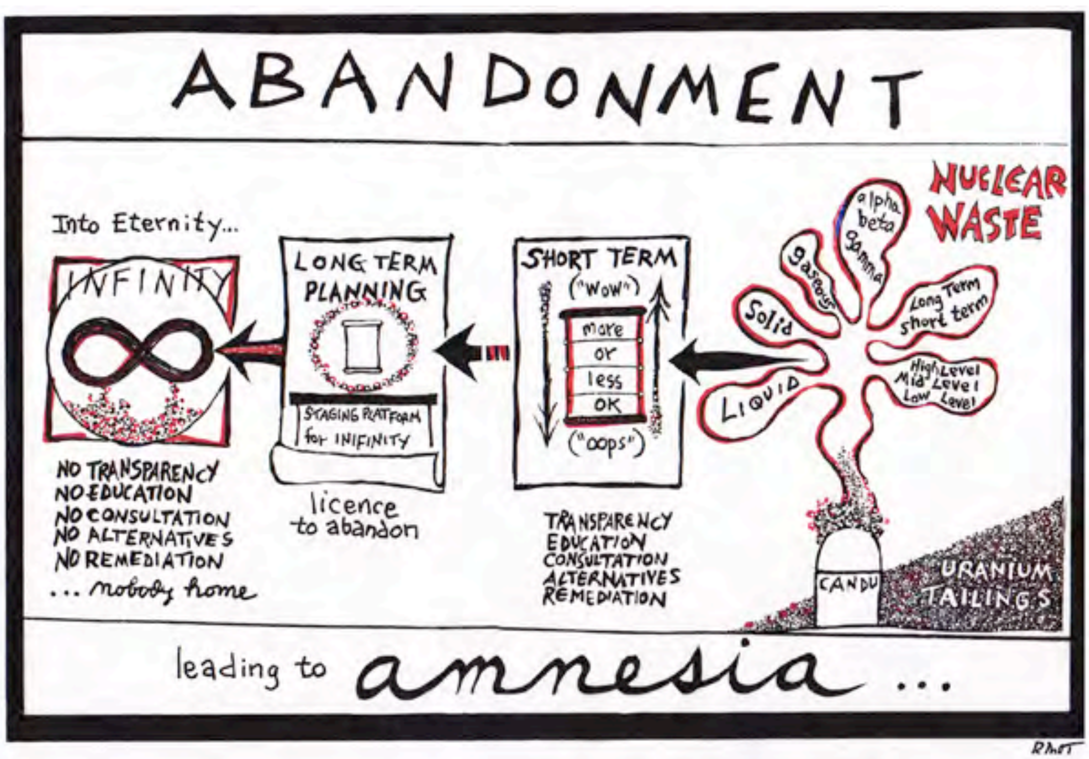
Conclusion 4.

CCNR recommends that NRC elaborate a set of rules and policies related to the concept of Rolling Stewardship as applied to the intergenerational management of irradiated nuclear fuel, including detailed mechanisms for transferring responsibility for managing the wastes from one generation to the next, mechanisms for funding the long-term management of the waste including monitoring, retrieval, recharacterization and repackaging of the waste and reinstructing each successive generation.

Rolling Stewardship gives each generation the tools to deal with the wastes.



Abandonment leads to amnesia – future generations are at risk but ignorant.



2. Irradiated Fuel with High-Burnup

The dangers of major radioactive releases from spent fuel pools have been underestimated for decades. The precarious state of the spent fuel pool in Unit 4 at the Fukushima Dai-ichi nuclear station has focused the world's attention on the issues at stake. Calculations have shown that the inventory of radioactive cesium in that spent fuel pool alone is more than 80 times the total amount of radioactive cesium released during the Chernobyl disaster in 1986.

Msssive radioactive eleases from the irradiated fuel in a spent fuel pool could result from a prolonged loss of cooling, an accidental criticality accident [nuclear fission] brought about by a shift in the geometry of the spent fuel assemblies in the pool, or in the case of an extreme situation of overheating, a spent fuel fire igniting the zirconium cladding in adjacent irradiated fuel assemblies.

Malicious acts directed against the spent fuel bay could trigger such releases as well. These potential threats are exacerbated by the fact that the spent fuel bay is typically not located within the containment system, and is not reinforced against potential terrorist attacks.

The inherent dangers in storing irradiated nuclear fuel have been compounded by recent practices. Since the 1990s, NRC has allowed its licensees to increase the burn-up of the uranium reactor fuel dramatically by increasing the concentration of uranium-235. The resulting irradiated nuclear fuel has a higher fission product inventory and generates significantly more decay heat. The unique characteristics of high burn-up irradiated fuel have major implications for the potential environmental consequences of storage of such nuclear waste in spent fuel pools, in dry storage casks, and even in a geologic repository, yet NRC has failed to carry out a thorough and exhaustive study of these important implications resulting from its own licensing actions over the last 2 decades. As of 2008, the NRC allows reactors using uranium fuel to operate at the highest burn-up rates of any country in the world.

Some of these considerations are laid out in a Memo recently prepared by Robert Alvarez on the subject of high burn-up fuel – see Appendix III.

Conclusion 5.

CCNR finds that NRC assurances of the safety of temporary storage measures for spent nuclear fuel under both wet and dry storage regimes are not supported by adequate analysis of the consequences of using high burn-up fuel in commercial reactors. CCNR recommends that NRC refrain from all licensing decisions that may add to the inventory of high burn-up fuel in temporary storage pending the outcome of a public review process based on a thorough analysis of all safety implications of high burn-up fuel vis-à-vis such things as accelerated cladding degradation, added criticality potential, obstacles to safe transport of spent fuel, deterioration of spent fuel handling equipment, alterations in isotopic composition (source terms), as well as increased radioactivity and heat generation in any geologic repository or surface facility.

3. Final Thoughts

CCNR recommends that the current suspension of lciensing decisions by the NRC should be continued indefinitely until the NRC has established detailed plans for the long term management of irradiated nuclear fuel that is not based on the unwartranted assumption that a safe permanent walk-away disposal method will become available within a few decades.

Nuclear proponents often argue that a permanent walk-away solution to the nuclear waste problem is required so as not to burden future generations. If such a solution is not available, however, then in fact future generations have already been burdened. In such a case NRC has a resonsibility to address itself to the task of laying out a program of Rolling Stewardship that will make the burden manageable for future generations.

The NRC also has an obligation not to add to that burden unecessarily. For this reason the NRC policy allowing licensees to use high burn-up fuels should be throughly reexamined and reconsidered with an opportunity for full public input.

In eny event, the existing DGEIS is inadequate as a basis for NRC rulemaking.

~ *finis* ~

Appendix I

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

to the

Joint Review Panel

examining

OPG's Proposal for a Deep Geologic Repository (DGR)

For Low-Level and Intermediate-Level Nuclear Wastes

August 20, 2013

August 20, 2013, 2pm,
slightly edited from the official transcript

THE CHAIRPERSON: Welcome, Mr. Edwards. Please proceed.

DR. GORDON EDWARDS: Thank you very much, Madam Chair. I would like to thank the Panel for agreeing to hear our presentation.

Our presentation is going to be focusing on one specific aspect of this project -- which is really, we think, the most important and perhaps the most challenging for the Panel to deal with -- and that is the question of abandonment.

Right at the beginning of the Environmental Impact Statement from OPG, the fifth sentence in fact in the Executive Summary, reads, quote:

> "The DGR project includes the site preparation and construction, operation, decommissioning, and abandonment, and long-term performance of the DGR."
> *[As read.]*

Now, it is our contention that it is one thing to talk about packaging and monitoring nuclear waste in as safe a fashion as possible. This is something that we all, without exception, desire. We definitely want to keep this material as safely packaged, and out of the environment, and out of danger for human beings and other species, as well as we can. No question about that.

But really, we're dealing here with two separate projects and I believe that these separate projects must be decoupled and judged separately. One of the projects is the Deep Geological Repository [DGR]. The other one is a Deep Underground Dump [DUD].

First, the Deep Geological Repository. A repository is a place where things are carefully stored and monitored to be consulted and retrieved. The Library of Congress has a repository for books. These books are not to be abandoned. They're not to be neglected. They are to be maintained.

And if we talk about a deep geological repository as a place to maintain, store, package, monitor, and retrieve if necessary, and repackage if necessary, that is a repository. When you talk about closing it up and abandoning it, then you're talking about a dump. And this is the Deep Underground Dump.

We believe that it is incumbent upon you as Panel Members to clearly separate these two concepts in your mind, and clearly separate these two concepts in your ultimate decision and advice to the Government of Canada.

I would like to point out that the term decommissioning, as normally applied to a nuclear facility, means restoring the site to its virginal state as much as possible. When we decommission a nuclear reactor fully we're talking about not only removing the irradiated fuel, but also removing all the radioactive components and removing whatever radioactive contamination may have resulted through operation, and as much as possible returning the site to a "greenfield" status.

Now, that is not what is meant here by decommissioning the DGR. In fact, in decommissioning the DGR, they're not returning the DGR to its original state at all. They are turning it into a Deep Underground Dump.

So decommissioning the DGR is in fact commissioning a Deep Underground Dump. That's when the Deep Underground Dump actually begins to function as a nuclear facility, and the thing about this particular facility is that it is unmonitored, that the wastes are irretrievable, and that it is beyond human control, and that it has never any decommissioning unless nature decides to decommissioning it in its own way.

So I believe that this is a problem -- it really presents an unethical, unscientific, and untenable decision to be made by this Panel, based on existing scientific evidence. I simply do not believe that we have scientific evidence that allows us to predict the safe operation -- unmanned, unmonitored, and irretrievable -- over such enormous spans of time.

We have heard many times from participants in these hearings and elsewhere that we need a long-term solution to the nuclear waste problem. We want a long-term solution to the nuclear waste problem. I think I can fully subscribe to that on behalf of my organization. We need it, we want it. But where we differ is that we believe we do not have it.

Wanting is not the same thing as having. We want a cure for cancer. We need a cure for cancer. But we don't have a cure for cancer and to pretend that we do have a cure when we don't is fundamentally dishonest.

To pretend that we have a solution to the nuclear waste problem when we don't is fundamentally dishonest. And because of the potential danger of these materials over such a long period of time, it is unethical to proceed on that false assumption.

The Nobel Prize-winning physicist Hannes Alfven, who was involved in the early phases of the Swedish nuclear program, is quoted as saying: "You cannot claim that a problem has been solved simply by pointing to all of the efforts that have been made to solve it." And this quotation was made specifically in the context of nuclear waste.

What I would like the Panel to consider is the fact that the Proponent in this case, OPG, has a serious conflict of interest in proposing a deep underground dump.

That conflict of interest is hinted at in their own document in Section 1.2.2. This is the first volume of the environmental impact statement. They say, and I quote:

> "The Western Waste Management facility was originally developed with the concept that it would provide interim storage for the low and intermediate level waste until such time as a long-term management facility was developed." *[As read.]*

Notice: not 'dump', not 'disposal', but 'long-term management'.

> "The current structures have been designed for a minimum life of 50 years. These structures could, with proper maintenance, continue to safely store the waste much longer than 50 years." *[As read.]*

And here is the key sentence:

> "However, Canadians have indicated that they do not want to wait another generation for substantial progress to be made on developing long-term solutions for waste management." *[As read.]*

What is this indication that Canadians are not willing to wait? I would put it to you that the reason Canadians are not willing to wait is because they have been told repeatedly that it is not a problem, that nuclear waste is not a problem.

My organization, the Canadian Coalition for Nuclear Responsibility came into being in 1975, and at that time I frequently raised the question of nuclear waste. And on public panels I was told by representatives from the nuclear industry that nuclear waste is not a technical problem, it’s just a public relations problem.

I thought then and I think now that that’s a very revealing statement. It’s a public relations problem because the industry perceives that unless they can convince the public and the politicians that this problem has been solved, that they will not, perhaps, be allowed to build more reactors and to continue the nuclear enterprise.

So for them it is a life and death issue -- for the industry I mean -- to persuade people that they have a solution.

Now, I can understand that approach and I can understand sincere efforts made to find a solution. But once again, as Hannes Alfven says: “You cannot claim that a problem has been solved simply by pointing to all the efforts that have been made to solve it.”

By the way the nuclear waste problem that was framed at that time was the high-level radioactive waste, the irradiated nuclear fuel, largely because people were unaware of -- well, not only were they unaware of the high-level waste, but they were even more so unaware of the intermediate and low level waste which we’re talking about at these hearings. I will return to the connection between them.

So the conflict of interest really started emerging around 1976. In 1976, there was a Royal Commission Report from Britain written by a British nuclear physicist, Sir Brian Flowers, who was involved in both the civilian and military nuclear programs in Britain, and one of the conclusions that they reached is -- quote (this is page 81, paragraph 181):

> "...we are agreed that it would be irresponsible and morally wrong to commit future generations to the consequences of fission power on a massive scale unless it has been demonstrated beyond reasonable doubt that at least one method exists for the safe isolation of these wastes for the indefinite future."

That was in 1976, the Flowers Report.

In California, a couple of years later, under orders from the California Legislature, the California Energy Resources and Conservation Commission held extensive hearings on the subject of nuclear waste. The reason being that the California Legislature had said that they would ban any further nuclear reactors in California unless there was a demonstrated safe solution to the [nuclear waste] problem. So that's why these hearings were held. And when the California Energy Commission reported to the legislature, they said -- and I quote from the Commissioner, Emilio Varanini:

> "Excessive optimism about the potential for safe disposal of nuclear waste has caused backers of nuclear power to ignore scientific evidence pointing to its pitfalls. That's the real crux of what we found -- that you have to weigh scientific evidence against essentially engineering euphoria."

So at that time, which was, of course, some time ago, the message was sent out that California in fact would no longer license nuclear reactors based on the advice of the California Energy Resources and Conservation Commission.

Now, in that same year, in 1978, the Royal Commission on Electric Power Planning published a report called "A Race Against Time", [in which] they said -- quote:

> "Continuous monitoring of waste disposal research should be undertaken by an independent panel of experts....If adequate progress is not being made by...1985, a moratorium...on additional nuclear stations should be considered."

That was, by the way, taken from the Principal Findings and Conclusions of the report, [it was] not just a passing comment.

So I think that these findings of various bodies -- oh, I should also mention 1977. That (1977) was the first year to my knowledge that the federal government ever issued a paper dealing with the nuclear waste problem, even though nuclear waste -- high level nuclear waste, and all the other nuclear waste -- had been already accumulating for 30 years in Canada as a result of operation of various reactors. That (1977) was the year that the Hare Report was published, entitled "The Management of Canada's Nuclear Waste", I believe.

And following that, the House of Commons had committee hearings on the Hare Report. They received over 300 submissions from interested parties. And one of the parties that submitted was Robert J. Uffen, Dean of Engineering at Queens University, who was at that time Vice-Chairman of Ontario Hydro, and he recommended that there be -- quote:

> "No large nuclear program until it has been demonstrated beyond reasonable doubt that a method exists to ensure the safe containment of the long-lived highly radioactive waste for the indefinite future."

Essentially echoing the findings of the Flowers Commission.

So this was a very important date in the history of the Canadian nuclear program, because it basically sent a shocking message [to the nuclear industry] that they might not be able to continue if they didn't get on the job.

In fact, 1978, that same year, a very important year, was when the research program began, the 15-year research program into granite rock, granite plutons in Manitoba, which led to the Atomic Energy of Canada Limited [AECL] environmental impact document [on the Geological Disposal Concept] that was then studied by the Seaborn Commission for 10 years, from 1988 to 1998.

Well, here's the question. The question is: are we really dealing with a situation where we've solved the problem and now we're implementing it? or are we dealing with a situation where there is a public relations need to give the appearance that we've solved the problem?

What my organization would recommend to the Panel is that whatever decision you make regarding the Deep Geological Repository, that you should not approve the Deep Underground Dump at this stage.

I don't believe that the Panel has the competent assurance, on the basis of the present state of knowledge, scientific and otherwise, to really say that these wastes are going to be safe for the periods of time being considered, which literally stretch into the millions of years.

Let me just give you a couple of specific examples.

As we have seen in this particular project, there has been a conflation of the waste, there has been a consolidation of what wastes are supposed to go into the repository. First, it was only going to be low level waste and short-lived intermediate level waste. That might be possibly a matter of decades or maybe centuries, I presume.

But then, having seen that they were getting community acceptance and so on, they expanded it to include all intermediate level wastes, which includes components which are far more radioactive than any of the original waste considered -- far more radioactive.

The refurbishment waste, for example, the pressure tubes and calandria tubes and other items that are removed from the core of the reactor, are much, much more radioactive than any of the originally planned waste to go into this repository, and yet now those are being considered as well.

Each CANDU reactor has 7 to 9 kilometres of these radioactively-contaminated and activated pipes that all of which is going to go into this repository now, not to mention the steam generators, which are 100 tonnes each.

There's eight steam generators in each of the Bruce reactors, that's eight times eight is 64 steam generators, each one 100 tonnes, and then they're replacing those steam generators. So we have 128 steam generators just from Bruce alone. And then we're going to have the steam generators from the other reactors.

I am not saying that the steam generators are the most problematic. I'm simply saying, what are we getting ourselves into here? Now, we hear that they're even considering including the decommissioning wastes. In other words, they're going for broke. They're including all the radioactive waste from the nuclear industry except the ones that are specifically handled by federal policy, which is the high level radioactive waste, namely the irradiated nuclear fuel.

They have not even dismantled one single power reactor in Canada, not even the Douglas Point reactor, which has been shut down for decades, not the Gentilly-1 reactor which has been shut down for 35 years. When we recently asked the federal government as to whether they were going to dismantle the Gentilly-1 reactor, they said, oh, no, we're going to wait for another 100 years perhaps.

So there is a problem here in trying to say that we have a solution to a problem they haven't even began to quantify or to actually explore as to what is the full scope of these decommissioning wastes.

Now, if we talk about the steam generators in particular. I happen to have data as a result of hearings that were held in Ottawa. And the steam generators, the pipes inside the steam generators -- there's 5,000 of them in [each of] the Bruce steam generators, 5,000 small diameter pipes -- and they become contaminated because of the coolant that is circulating through them, the primary coolant.

We have a list of the radionuclides that were provided by Bruce Power, and we have americium-241, which has a 430 year half life; americium-243, which has a 7,000 year half life; plutonium isotopes, which includes, of course, plutonium-239 with a 24,000 year half life…. Twenty-four thousand years!

It turns out that 91 percent of the [mass of] radioactivity inside the pipes of the steam generators are plutonium isotopes. There are five plutonium isotopes. Question, how did they get there? Well, they got there because they were carried by the water that flushed them out of defecting fuel elements.

And although it's a very small quantity in grams -- we're only talking about less than 4 grams, it's actually 3.7 grams of radioactive material in one steam generator, which means that you have only 3.27grams of plutonium -- but that's enough to give 4 million overdoses to atomic workers, because the permissible level, the permissible body level for plutonium in an atomic worker is 0.7 micrograms.

So if you figure it out, just that small amount of plutonium in one steam generator, that's enough, theoretically, to give more than the body burden that is permissible for four million atomic workers.

I'm simply pointing this out because we have to really use our imagination to grasp the scale of what we're talking about. 24,000 years ago there were no Great Lakes. The Great Lakes were only formed about 10 or 15 thousand years ago, so there were no Great Lakes back then. So what are we talking about? The Pyramids of Egypt are only 5,000 years old.

And what's more, something that even people in the nuclear industry sometimes don't realize is that whenever a plutonium-239 atom disintegrates, it turns into a uranium-235 atom, which has a 700 million year half-life. So all the atoms of plutonium in the steam generators are going to turn into atoms of other materials which have half-lives measured in the [hundreds of] millions of years.

Enough said. I just feel that when we talk about a repository, what our organization advocates is a new concept based on honesty. And this new concept based on honesty is this. We cannot decide here and now not to burden future generations with this. We have, in fact, burdened future generations with this. And it's too late now to say we wish we hadn't done it.

So what we have to do is to adopt a forward-looking policy of rolling stewardship. And rolling stewardship means that we package this stuff as carefully as we know how to do, we monitor it continuously, as I hope we do, and we do repairs as necessary and take corrective measures as soon as possible to prevent any leakage or contamination from escaping.

Now, this burden has to be passed on to the next generation. And the next generation has to be prepared to repackage these wastes, to retrieve them and repackage them and to continuously monitor them. And they have to pass that on to the next generation.

And so it has to roll forward from generation to generation with good documentation, with very good instructions as to what should be done with this waste. Now, whether that's done underground or above ground is of little consequence to me as long as we don't fool ourselves into thinking we have a solution to this problem once and for all. Because I don't believe we do.

Just before I move onto what we would like the Panel to consider recommending, I would like to point out a couple of other things. One of those things is the volume of waste involved.

I heard at a Canadian Nuclear Society meeting two years ago, from the man who is in charge of nuclear waste management at Point Lepreau nuclear station, that they had built two new buildings to house the refurbishment waste that they expected to get by refurbishing that reactor. They ended up with five times the volume of the waste they had anticipated. Five times the volume.

And he said the main reason for this was because, unfortunately, with radioactive waste, when it comes in contact with uncontaminated material, that becomes radioactive waste too. And so the amount -- the volume of radioactive waste, through imperfect management -- grows and grows and becomes larger and larger.

And of course, this happens too with containers. As OPG readily admits, the containers will disintegrate in the underground dump. Well when those containers disintegrate they too become radioactive waste. And even the surrounding environment. If it was a soil situation we were dealing with, the soil becomes radioactive waste.

In fact, there's one experience in the U.S.A. from this Department of Energy document called "Closing the Circle on the Splitting of the Atom". It's a U.S. Department of Energy publication. And on page 7 they refer to Pit Nine. Pit Nine is a radioactive waste burial ground. Quoting from the document:

> "From 1964 to 1969, approximately 150,000 cubic feet of plutonium-contaminated and low-level radioactive waste was buried here. Record keeping that does not meet today's standards, and failed waste containment, have made Pit Nine a daunting remediation challenge for engineers, who must now sample these wastes, exhume them, and treat them [in a different fashion]."

Thermally it says here. I'm not sure exactly what that means -- "treat them thermally".

So you see, the danger is that if we're wrong about having a solution, then we're leaving to future generations the responsibility of Rolling Stewardship without the decency of telling them that that's their job.

I think we have to have the decency to tell future generations that, "Unfortunately, you are going to have to be prepared to spend time and energy and money on this. But it's not so onerous that it can't be done. We are doing it, and you can do it, and I'm afraid you must -- until such time as we actually do have a solution".

It's important to realize that as far as high level waste goes, the United States Government, the US DOE in this case, has in fact tried eight times in the United States to locate an underground waste repository for high level radioactive waste and they have failed all eight times, the most recent failure being Yucca Mountain.

The first [failure] that I was aware of was in the 1950s when Milt Shaw from the Atomic Energy Commission went to the U.S. Congress and demanded funding to immediately start emplacing waste in a salt mine in Lyons, Kansas, which he assured the Congress was the safest place in North America for disposing of high level radioactive waste. It turns out it wasn't. Milt Shaw was fired and that was the first failure. Of course you know of other failures -- in Germany, the Asse II salt mine, and so on.

So what is it that our organization would like to see this Panel consider?

Whatever your decisions about the DGR -- and I think there are other concerns that we could have addressed there but we're not focusing on that -- we feel that the Panel should not, at this time, give approval to the Deep Underground Dump. We should say, "Look, this is not something that we can approve at this point in time". Although we need to keep working towards a solution, we're not there yet.

Secondly, we would like the Panel to consider that if the DGR proposal is in fact inevitably predicated on the assumption that it turns into a dump, then we think you should not approve the project at all.

Ontario Power Generation has said that the above ground storage is safe and it can be continued and there's no reason why repackaging could not occur and so on. So I don't believe, based on the evidence submitted to the Panel, that there's any reason why the Deep Geological Repository must be constructed. The only reason I can see for that is so that you can then abandon the waste.

And the final point is that we feel that the Panel should realize that when we come to talking about permanence, about infinity, about eternity, that we need to have a federal policy. And we do not have a federal policy. The only federal policy we have at the moment is governing highly radioactive waste.

But the stuff in the intermediate level waste and so on is really the same material in a more dilute form. These are the same radionuclides that are in the ion exchange resins, in the steam generator tubes, in the various components that have become contaminated. And therefore, we need a federal policy on all other forms of radioactive waste.

What are we going to do in Quebec with the low and intermediate level waste from Gentilly-2? What is New Brunswick going to do with its low and intermediate level waste? Are they going to be welcome here in Kincardine? So far, no. Ontario Power Generation says, "We're going it alone".

We feel that this is a wrong approach. Nuclear power has been a national program from the outset. This is a federal panel, I believe, and you're reporting to the federal government.

I think that one of your recommendations should be that Canada needs to have public hearings leading to a federal policy on all forms of radioactive waste other than the irradiated nuclear fuel.

Thank you very much.

THE CHAIRPERSON: Thank you. I would like to lead off the questioning and then I'll go to my fellow Panel Members. So Mr. Edwards, would you explain to the Panel how the risk would be lower with rolling stewardship?

What is your evidence for such a strategy working? For example, is there evidence for such a strategy working with other hazardous materials such as pesticides, for example? Do you have any evidence of successful rolling stewardship beyond one or two generations?

DR. EDWARDS: Well that's quite a challenging question. I'd certainly be willing to do that as an undertaking to search for such examples and submit them to the Panel. I don't have them up my sleeve.

But I would like to point out that in toxic waste dumps, I put it to you that the human race has never successfully disposed of anything. When we have dumped toxic waste -- as in the Love Canal example or poison gas left over from World War I or the injections of toxic waste by Dow Chemical into deep underground boreholes in Sarnia, which came up as toxic blobs in the St. Clare River -- when we have tried to pretend that we have solutions to these problems and just dumped things, they, in many cases, have come back to cause terrible problems.

Now, I feel that the present stewardship here at Bruce is a good example of rolling stewardship. I don't think the people who are managing it today are necessarily the same people who were managing it years ago. Rolling stewardship is simply a question of making sure that people are on guard, they're monitoring and when they see a problem, they take steps to correct it.

The difficulty with these disposal ideas -- or abandonment, rather -- is that nobody is there to monitor, nobody is there to correct, and so if it does leak seriously -- as, by the way, in the Asse II Mine in Germany -- apparently it was leaking for about, I believe, 10 years before it was actually reported as being a problem. So there is a danger. There's a difficulty there in terms of covering up, so one has to be careful about that. What we need here, and this is very important, we need to have independence.

You'll notice that one thing that I didn't emphasize in my presentation was that when the Royal Commission on Electric Power Planning recommended that there be a monitoring of research in waste disposal, they said "by an independent panel". And in the text, they make clear what they mean by that is independent of the nuclear industry and its regulator. That's what they mean by independent.

Similarly, when the Seaborn Panel published its report, they recommended a nuclear fuel waste agency that is at arm's-length from the nuclear industry. Independence is essential.

And the Nuclear Waste Management Organization is not. The Nuclear Waste Management Organization is a creature of the very industries that create the high level waste. So there is, unfortunately, in that situation, a built-in conflict of interest. What we need is independent monitoring.

I believe that we have, in our society, the capability to maintain this kind of legacy of environmental stewardship, to look after a problem as it goes through time and not to just forget about it. We can't afford amnesia.

I'm reminded of the findings of the environmental panel at Elliott Lake regarding the [radioactive] tailings that were being stabilized for long-term management. In their report, they said that it must be recognized that this is a never-ending environmental threat and it requires never-ending attention.

Now, I'm paraphrasing. I don't think they used the word "never-ending", but that was essentially their finding, that you can't say this is now solved, [you can't just] walk away from it. You have to regard it as a perpetual challenge; there is a need for perpetual monitoring and repair if necessary, [and] retrieval.

THE CHAIRPERSON: Mr. Edwards, I'm following your reasoning, but I really didn't hear much evidence for successful examples in human society for beyond one or two generations.

So I would like that as an undertaking from your organization, please. This will be Undertaking Number 21, for the Coalition for Nuclear Responsibility to provide the Panel with some evidence for, I would say, beyond two generation stewardship. And it doesn't have to be nuclear, just of anything. That would be very helpful.

UNDERTAKING NO./ENGAGEMENT No. U-21:
By the Canadian Coalition for Nuclear Responsibility to the JRP to provide examples of rolling stewardship beyond one or two generations. Examples need not be limited to the management of nuclear waste.

THE CHAIRPERSON: Dr. Muecke?

MEMBER MUECKE: Just for background for myself, could you tell me a little bit about your organization, size of membership?

DR. EDWARDS: Yes. It's a very low-budget organization. It was founded in 1975. I became involved myself in 1972 in the nuclear issues.

In 1975, there were 30 people who joined in the basement of 2010 Mackay Street in Montreal to form the Canadian Coalition for Nuclear Responsibility. And when it was formed, it was conceived of as a pan-Canadian coalition of groups.

Invitation letters were sent out across Canada to environmental groups to join the coalition. And the purposes were twofold. One was to provide a clearinghouse of information about nuclear issues to communities and to organizations. And the second was to present a united front to the Government of Canada requesting a public inquiry into the hazards and benefits of nuclear power for the benefit of the public and for the benefit of the decision-makers.

We felt that, since such a debate has never been held in our federal Parliament, an inquiry would be a good way to get all of the pro-nuclear and anti-nuclear evidence on the table and weigh the pros and cons, and it would be an educational experience for all concerned. So that's what we were involved in.

Now, the Coalition lasted as an actual formal coalition up until about 1981. At that time, there were no more nuclear reactors being built in Canada because of the situation, and the result is that we had to retrench.

So we restructured and became fundamentally a core group based in Montreal which now maintains good relationships with groups across the country, about 100 of them, who are informal members of the coalition but not formally so because we can't afford to have national conventions where we bring everybody together, or annual public meetings.

So consequently, it has become primarily a kind of a Montreal-based think tank with a Board of Directors of about 12 people, varies from 10 to 12. And we have a lot of good connections with other groups across the country. Is that helpful?

MEMBER MUECKE: Yes, thank you. That was more than helpful.

DR. EDWARDS: We've also been intervenors at many, many hearings. And we maintain a Web site, which records a great deal of this intervention. In terms of the nuclear waste issue, I think we were intervenors in virtually all of the things that I referred to before.

MEMBER MUECKE: Thank you. Now, you emphasized abandonment. And on the other side of the coin, possibly, is retrieval. And we have heard from OPG a couple of days ago about retrieval, so I'm actually going to address my question to OPG because at that time, if I understood correctly, OPG's response about retrieval was that the waste would be retrievable even after closure of the DGR.

Now, my question is here: is this a theoretical statement? or is it based on what is known about current levels of technology? and what is the international experience about retrieval so far?

MR. FRANK KING: I believe when this came up the other day, Dr. Muecke, it was described as a continuum. When you put the waste in the repository, it's easier to retrieve. As the repository gets further and further in, I think it becomes more difficult.

I'll just mention a couple of the stages. When you put it in by forklift, you could -- if you wanted the next week to take it out by forklift, you back it out the same way. It's just reversing the process.

Once you put in closure plugs or access tunnel closure plugs -- which are about 10 metres long, concrete monoliths -- then, of course, it becomes more difficult. Either you have to remove it or bypass it to get back to the emplacement room.

After you put the shaft in, it becomes very much more difficult, of course, but is it impossible? No. It would be very expensive, but Canadians are pretty good at sinking shafts and going and getting minerals at great depths.

And it was in that context where I think Mr. Wilson responded to that question that it's physically possible, but at great difficulty.

MEMBER MUECKE: After closure, you have gas generation, disintegration of containers, obviously. Could you take us to that stage?

MR. KING: As I said, the longer you get away from the time that the waste was in place, the more difficult it gets. But it is not impossible.

And if the waste container -- the waste containers that have the highest activity waste, the retube waste, the ion exchange resins -- there's a presentation on Monday, I believe, on management of low level waste.

Ms. Morton will be going through that presentation showing pictures of waste containers and the ILW waste container, she has pictures of those. And they are very robust containers.

And at closure in the repository, 60 percent of the activity is retube waste. And these are in stainless steel, thick-walled, robust containers. Those would be easily retrievable for long periods of time.

The less active wastes are in thinner-walled containers, but it is not impossible to [retrieve] the lower activity waste. I think you've seen pictures of people carrying bags of waste. And it is not a remote handleable problem.

So I think that's all I can offer.

MEMBER MUECKE: What is the international experience in retrieving waste that has been stored in deep geologic repositories?

MR. KING: As of right now, there is only one existing in the world deep geologic repository. That's the WIPP [Waste Isolation Pilot Plant] facility. And there's been no need to retrieve of any of that waste, to my knowledge.

If you went to a shallower repository, then -- for facilities that were designed specifically for radioactive waste, and I would include in that the two repositories in Finland, the SFR facility in Sweden -- then I'm not aware of any need to retrieve wastes from those facilities, either.

There are some other facilities in the world, and Dr. Edwards had mentioned one of them in the Asse II facility in Germany, which was not designed as a waste repository. It was an old salt and potash mine from the 1960s where waste drums were put in at the beginning on an experimental basis, and they have a very significant retrieval issue with that repository.

MEMBER MUECKE: Thank you.

MEMBER ARCHIBALD: Dr. Edwards, just one small question, and this, again, concerns what Dr. Swanson had asked. In your opinion, is the rolling stewardship approach to waste control, where one -- or a group or whoever -- forwards the responsibility of risk and cost to future generations without their approval, a truly sustainable and ethical approach to managing wastes?

DR. EDWARDS: Yes, I believe it's the only one. I think it's the only one that's based upon sound ethical principles and sound scientific principles.

If you don't have a solution to a problem, you manage it as best you can. I'm reminded -- my field is mathematics; I'm a retired professor of mathematics. And there's an old saying in operations research that a manager would rather live with a problem he can't solve than accept a solution he doesn't understand or doesn't trust. I think that that's the situation we're in.

It's better for future generations to be well informed and [for us] to make no bones about it: “This stuff is dangerous. This is what it is. Here's the inventory. Here's a manifest. Here are instructions as to what we did. And you can probably do better because you may have better ways of packaging it. You may even work out a solution. You may find a way of neutralizing this waste or rendering it harmless.

But you won't have to, in the future, be faced with some environmental leakage which is intolerable which will lead you to break into an abandoned site knowing nothing about what was there, having no documentation, no inventory, such as they did at Pit 9 in the DOE.” They didn't know what was buried there because nobody documented it.

So when we talk about abandonment -- and that's not my word, it is OPG's word; they are using the word abandonment, and they use it not just once; they use it several times, even in the opening summary -- abandonment is part of the plan. When you talk about abandonment, I think you are talking about washing your hands of responsibility because you are saying, “Nature, don't dig here. Men, don't dig here. We are finished.”

Now, I believe that this is convenient for the nuclear industry. Whether it is, in fact, a solution, however, remains to be seen.

Being a mathematician, I'm aware of the limitations of mathematical models. The difficulty of getting nuclear waste into an undisturbed geological repository is, you can't do it without disturbing it. And when you disturb the repository, you can never restore it to the initial – to its original integrity. There's no way that we know how to put a geological formation back together again.

We talked about our expertise in mining. Nobody doubts that you can dig a shaft and dig things out. The question is; can you restore the geology back to where it was as nature had it? And the fact is, we don't know how to do that. So of course, the shaft is one of the Achilles heels of the whole project.

There's also this question of gas generation, the chemical changes that are going to take place after abandonment. What it really amounts to is a vast uncontrolled scientific experiment.

Science has grown up with the idea that we do experiments that are replicable and that can be tested, and they have always a beginning, a middle, and an end. When the chemist does an experiment in the lab, he thinks the experiment is over when he flushes the chemicals down the toilet or the sink but, in fact, the experiment's not over. It's continuing in the pipes and perhaps in the river and perhaps in the ocean. The experiment's not over. We just stop paying attention to it, that's all.

So when you have indestructible materials, materials that we cannot wish out of existence, we are conducting a vast uncontrolled scientific experiment. And we're saying to the future generations, “Good luck. Hope it doesn't trouble you, but if it does, you're not going to have any guidance from us.”

THE CHAIRPERSON: Thank you, Dr. Edwards. CNSC, I believe you wanted to provide some explanation around licensing, including abandonment?

DR. PATSY THOMPSON: Yes, if I could. And perhaps because of the questions that Dr. Muecke asked about retrieval, I would ask that Don Howard provide a couple of examples of situations where these activities are taking place.

And so for the context for licensing, what I wanted to say is that in the international literature from the IAEA, for example, or other organizations providing guidance for deep geologic repository, the terms that are usually used are closure and post-closure.

And so for the work that is being done for this project, that language was essentially transferred to the language in the licensing phases under the *Nuclear Safety and Control Act* and the Regulations.

And so the phases of licensing are site preparation, construction, operation, decommissioning, and abandonment. And so the example that Dr. Edwards provided in terms of nuclear power plants being decommissioned, actually, the last licence that a nuclear power plant operator would receive after decommissioning and demonstrating that the site is stable would be an abandonment licence.

And the abandonment licence is the equivalent of what is, in international documentation, the post-closure phase. And so it would be done at a stage where the site, after a long monitoring period, was demonstrated to be in a stable, safe condition and that the safety case would have been updated using all of the information that would have been acquired through all the previous phases of licensing.

And so perhaps Mr. Howard could talk about the question that Dr. Muecke asked about waste retrieval.

MR. HOWARD: Don Howard, for the record. I'd just like to add a little bit to Dr. Thompson's comments in that the CNSC has issued licences to abandon. Most recently, we did issue a licence to abandon to the -- Dalhousie 9 University for the SLOWPOKE reactor that was decommissioned.

The application for a licence to abandon is accompanied by the end-state decommissioning report; in other words, demonstrating that they have met their end state objectives and that they have cleaned up the site to pre-determined levels that were in their decommissioning plan which is verified, then, by the Canadian Nuclear Safety Commission. And then, based on that information, we would issue a licence to abandon.

Now, some examples of retrieval, two that come readily to mind -- and I'm afraid they're not like deep. They're more near surface, a few tens of metres. One project that we're currently undertaking is in the Port Hope area where we're taking the Welcome Waste Management Facility and the Port Granby Waste Management Facility where the waste will be retrieved in the next seven years and transported and put into an engineered long-term waste management facility.

Another example that comes to mind is up at the Chalk River facility. Back in the 1950s, approximately, for the operation of the NRX reactor, some of the waste which was put into 45-gallon drums, a series of four to six drums were put on a concrete pad and then encased in concrete and buried, and these are what we call cribs.

And which Atomic Energy of Canada has now undertaken a program and they have retrieved a few of those and they are continuing to retrieve the remainder of them at Waste Management Area B up at Chalk River.

So basically, they do present issues in retrieving but they're well-planned, well-executed, and under regulatory oversight. So basically the material can be retrieved if its well-planned and taking into considerations and analyzing that, you know, this material has been in the ground for 50 plus years, so -- yet they do present some challenges, but if they're well-planned and well-executed it can be done.

MEMBER MUECKE: And just to follow-up on that, if in these cases, retrieval had been pre-planned, in a sense, would it have made the present cleanup job easier, and is pre-planning of retrieval perhaps an option?

MR. HOWARD: Don Howard, for the record. Obviously, in the 1950s if the plan was to retrieve it 50, 60 years later and you plan that ahead, it's almost like using the example that if you were to develop a process and in designing that process you think about, okay, here's the process, here's what I want to accomplish, what waste am I going to produce; so then I have to think about what the wastes I'm going to produce in order I -- can I manage that when I produce it?

So if you bury something and the intent is to retrieve, then you take that into consideration.

Again, with the geologic repository that the DGR is proposing, in this case here is that -- my opinion is that it can be retrieved. You have to plan it out. You have to take into consideration some of the difficulties that you would encounter after -- depending on the length of time that this material has been underground and certain conditions that you may encounter, but it can be retrieved.

MEMBER MUECKE: Sorry, maybe it's semantics here, but in terms of what you're telling me . . . were you implying that pre-planning of retrieval may be an option? or are you saying what OPG presently presents the case is retrieval is possible?

MR. HOWARD: Don Howard, for the record. I guess what I'm saying is that retrieval is possible but is not being planned.

MEMBER MUECKE: Thank you.

DR. THOMPSON: Dr. Muecke, if I could just add some information in terms of what Mr. Howard has presented. One of the things he mentioned is that it's being done under regulatory oversight and there's a number of programs that the licensee had to put in place to meet regulatory requirements.

One of those programs is the radiation protection program. And so in the same fashion if retrieval in the Deep Geologic Repository was being considered, the issue that Dr. Edwards talked about in terms of the gas that's been generated -- you know, remember that one of the intrusion scenarios is drilling to the repository in the area, and the dose to the driller was 0.8 millisieverts per year. So that's not a very high dose. So we agree that gas will be produced. It's been taken into consideration, but the reality is it's not highly toxic. The dose is below the public dose limit.

But having said that, if we were to, at some time in the future, retrieval would be necessary, it would be done under regulatory oversight with the radiation protection program that would look at the conditions and the precautions that would need to be taken by workers. But with the information we have in the assessment the doses would not be significant.

THE CHAIRPERSON: Thank you. Dr. Edwards, we do have some questions for you from other participants.

DR. EDWARDS: Is it possible for me to make some comments following on what was just said by CNSC, or not? Because I do disagree with some of the things that were said.

THE CHAIRPERSON: I think it's really -- the purpose of your ---

DR. EDWARDS: Yeah, I understand.

THE CHAIRPERSON: --- presentation is to provide us with evidence, then ---

DR. EDWARDS: Right, I understand.

THE CHAIRPERSON: --- we test ---

DR. EDWARDS: --- Okay, I'm just --

THE CHAIRPERSON: --- your evidence.

DR. EDWARDS: --- asking.

THE CHAIRPERSON: Yeah. Mr. Bourgeois, did you have a question?

MR. EUGENE BOURGEOIS: Thank you, Madam Chair. I actually have two questions for Dr. Edwards, if I may.

The first is, does Dr. Edwards have any insight into how and when the definitions for high level waste and used fuel wastes came to be changed so that all high level wastes now are referred to as used fuel wastes, or as, in the 1980s, the IAEA identified high level waste separately from used fuel wastes, and the Province of Manitoba codified those definitions in its *Nuclear Waste Act*?

THE CHAIRPERSON: Dr. Edwards, you could try, but I think CNSC might be able to help out with this as well.

DR. EDWARDS: No, I can't cast much light on that. But I would like to say that I do believe that the classifications that we have of radioactive waste are woefully inadequate. Just classifying them as high level, low level, and medium level doesn't do any kind of justice to the problem.

I think that they were based on the problem of workers managing to store these wastes in the short-term. What the workers need in order to be able to transport the waste, what levels of protection they require, that's a totally different question as to how toxic these materials might be if they escaped into the environment.

And so I think that we have a need for a complete revision of our classification scheme of radioactive waste in Canada. It's very much inadequate.

THE CHAIRPERSON: CNSC, could you shed some light on this?

MR. HOWARD: Maybe I'll start off with the International Atomic Energy Agency's definitions. Essentially, internationally, when we talk about high level waste, we're talking about spent fuel, irradiated nuclear fuel. Reprocessing waste is also high level waste in the international area.

And basically the high level waste is material that contains long-lived isotopes, consideration for heat dissipation has to be taken into consideration, and [it] can go critical. So internationally, that is the scene and that's how the International Atomic Energy Agency has defined it.

In Canada, we do not reprocess waste or spent fuel. So therefore, we do not have reprocessing material. Maybe I'll quantify that a little bit. We have a bit up at Chalk River where they did do some research work on reprocessing, but it's very small in nature.

But generally, the bulk of the material in Canada is irradiated nuclear fuel, not reprocessing waste, and therefore, that's why we kind of make the link high level waste equals irradiated fuel for Canada. On the international scene, as I said, there are other types of wastes for reprocessing, which are classified as high level waste as well.

THE CHAIRPERSON: Mr. Bourgeois, did you have other questions?

MR. BOURGEOIS: Yes, and thank you for the answers. The other question I have concerns an experience I've had where the nuclear industry has made threats to me not to speak out publicly.

And I wondered has the nuclear industry made any threats, either in writing or warnings, to Dr. Edwards about speaking publicly?

THE CHAIRPERSON: Dr. Edwards, I'll leave it at your discretion if you would like to answer this question.

DR. EDWARDS: Well, I would say yes I have, but I don't think these are things that are easy to document and so I can only say that yes I have.

THE CHAIRPERSON: Ms. McFadzean?

MS. McFADZEAN: On Monday, I asked the question about the retrieval issue and I'm very happy to see that Mr. Muecke has picked up on that again because I did receive the same answer on Monday that he received today.

And you kindly asked me, Dr. Swanson, if I was satisfied with the answer and I said no, but that there were people behind me waiting to ask questions.

So I want to just go back since there's an opportunity today to talk about retrieval and say that my question is still on the floor and I don't feel that it has been adequately answered.

I'm understanding from today's answer that we may be looking at 50 years. There's some experience with 50 years in a pre-planned retrieval situation in another kind of waste repository other than the one we're talking about, so I guess my question still stands.

Do we have sufficient evidence that, should there be an accident or malfunction, that we will be able to retrieve this waste over the long-term?

I need to put that out again. I don't feel that it has -- I don't feel comfortable that it's been answered.

THE CHAIRPERSON: So Ms. McFadzean, I think the key words in your question are "do we have sufficient evidence". Yes? OPG, would you like to address this?

MR. KING: Frank King, for the record. I really don't have too much additional to add to what I said earlier. Maybe there's just two points though. What is going into the DGR is waste. There isn't any intent to retrieve. There isn't an identified need to retrieve. If there was an intent, we would call it storage. But in international definition, disposal is where there is no intent to retrieve. That's the difference between storage and disposal.

If, at the time this facility gets licensed and goes ahead, at the time of decommissioning licence I think this would be looked at in great detail prior to getting authority from the CNSC to close the repository.

Society, at that time, would want to have an extremely high level of confidence that there would be no need foreseen at that time to retrieve because you are making it much more difficult, as I described earlier, by closing the shaft.

THE CHAIRPERSON: Thank you, Mr. King. Dr. Greer?

DR. SANDY GREER: Thank you. I have a question for Don Howard. You mentioned that in Port Hope the CNSC is involved with taking waste management, retrieving waste management from a facility there and putting it somewhere else in a long-term facility in the next seven years.

Could you please clarify how you would characterize that waste? Is it low, intermediate or high? Why is it being retrieved? Outline the process of retrieval and identify where is the long-term facility. Where it is going to be taken? Thank you.

MR. HOWARD: There are essentially two projects in Port Hope. I'll talk about Port Granby, which is the simpler one. Port Granby is located along the bluffs of Lake Ontario, and the bluffs are eroding, so basically the intent is to retrieve that material and move it inland to an engineered long-term facility. So that's the reason why that one is being looked at. Otherwise, there would have to be some major shoring of the bluffs and stabilization of the waste itself at Port Granby.

Now, the other thing is the Welcome Waste Management Facility -- and before I go on to that one, something came to mind. Basically, in answer to Dr. Greer's comment, we are not doing the work. This is Atomic Energy of Canada that's been contracted by the federal government to do this work. We are the regulatory agency. We are the licensing agency and the compliance agency to ensure that they do it safely and protect human health and the environment, so I want to make that clear. CNSC is not doing the work.

The Welcome Waste Management Facility: basically, there's two components to that.

A lot of the uranium contaminated soil was deposited near surface and a very thin coat of overburden was placed on it, so that needs to be moved into a long-term waste management facility.

In addition to that, a lot of the material in and around the conversion facility in Port Hope -- there's some uranium-contaminated soil in that area in some of the municipal lands and in some back yards of some of the property owners -- so all of that is going to be retrieved and moved into a long-term waste management facility.

Now, all of this waste is what we would classify as low level, long-lived radioactive waste.

DR. GREER: Thank you. I'm sorry if I missed where you said it was going, or has that been identified yet?

THE CHAIRPERSON: Mr. Howard, can you clarify again just quickly where it's going in both instances, Welcome and Port Granby?

MR. HOWARD: For Port Granby, the material is going to be retrieved and is being moved on property that is owned by the federal government, if memory serves me right, about 700 metres inland away from the bluffs. And in the Welcome Waste Management Facility, the waste is going to be -- is going to remain on site, just retrieved and put into a more engineered facility. And as I said, the material in the town itself will be retrieved, transported to this facility.

DR. GREER: Thank you. I just wanted to know whether you're using a new process to undertake this activity of retrieval and storing it somewhere else, or has this been done before?

MR. HOWARD: Again, in moving this material, it's -- we're moving soil. Soil has been moved for quite a while. Under our regulatory framework -- basically Atomic Energy of Canada is moving soil, but this is radioactive soil, so basically, they have to have the proper programs and procedures in place, such as radiation protection, and they have to meet transportation requirements for moving radioactive soil.

THE CHAIRPERSON: Thank you. Okay, so that would conclude the questioning. Thank you very much, Dr. Edwards. Oh, yes. Could you give us an estimate for the date of the undertaking you agreed to, which is with respect to providing us with evidence on rolling stewardship?

DR. EDWARDS: I will provide the evidence as soon as I can. How soon would the Panel require it? by the end of the hearings? or earlier than that?

THE CHAIRPERSON: By the end of the hearings would be sufficient.

DR. EDWARDS: Okay. I would like to add that rolling stewardship is a relatively new idea, but I think it's a viable idea and it's really prompted by the failures of the human race to dispose of anything.

THE CHAIRPERSON: Thank you. So if we could suggest October the 11th, which is actually the day immediately before the final day, that would be very much appreciated. Thank you so much.

Appendix II

:

Additional Information on Rolling Stewardship

submitted to the

Joint Review Panel

at their request

by

Gordon Edwards, Ph.D.,

and

Robert Del Tredici

October 30, 2013

UNDERTAKING No. U-21:

from the

Canadian Coalition for Nuclear Responsibility

to the

Joint Review Panel

Examples of Rolling Stewardship Beyond One or Two Generations.

by

Gordon Edwards, Ph.D.

and

Robert Del Tredici

All Photos and Graphics by Robert Del Tredici

October 30 2013

INTRODUCTION

Repository versus Dump

Ontario Power Generation (OPG) is seeking permission to construct a Deep Geologic Repository at Kincardine Ontario, less than a mile from Lake Huron, to store all of the nuclear wastes from all of Ontario's 20 nuclear power reactors, except for the irradiated nuclear fuel which is subject to a federal law called the Nuclear Fuel Waste Act.

The Canadian Coalition for Nuclear Responsibility (CCNR) is urging the Joint Review Panel to decouple two quite different aspects of this proposal: the first is OPG's plan to construct a Deep Geological Repository (DGR) where nuclear waste can be securely stored and monitored in a safe and retrievable fashion; the second is OPG's plan to abandon those wastes at some time in the future, closing and sealing the underground facility, thereby creating a Deep Underground Dump (DUD) which will forever after remain unmonitored, unmanned, unregulated – eternally beyond human control, right beside Lake Huron.

CCNR believes such a DUD should not be approved. CCNR believes it is both unethical and unscientific to abandon nuclear wastes – many of which will remain dangerous for hundreds of thousands, indeed even millions of years – based on the hope that radioactivity will never find a way to migrate out of the dump at some future date, entering the Great Lakes and thereby endangering the environment of living things.

Link for CCNR written submission: http://www.ccnr.org/CCNR_CEAA_DGR.pdf
Link for CCNR oral presentation: http://www.ccnr.org/DGR_GE_Transcript.pdf

The Concept of Rolling Stewardship

In both its written and oral submissions, CCNR has urged the Joint Review Panel to firmly reject the abandonment option in favour of Rolling Stewardship – an intergenerational waste management concept whereby each successive generation passes on the knowledge and provides the necessary resources to the next generation, so that nuclear wastes are never placed beyond human control and are never left unattended.

Rolling Stewardship is not intended as a mere caretaker operation, but as an active, fully involved effort to continually improve security by retrieving, recharacterizing and repackaging the waste in ever more protective ways, until such time as a genuine solution to the waste dilemma is found – perhaps in the form of a new technology that can destroy the waste, or render it harmless, or remove it permanently from the Earth.

The concept of Rolling Stewardship was first introduced in the 1995 U.S. National Research Council study, "Improving the Environment." In that report, the Regulatory Measures Subcommittee called direct attention to the concept of "Rolling Stewardship" as an important option for addressing contaminated sites that pose significant cleanup challenges. "Rolling stewardship" means planning for stewardship one generation ahead; by doing it one generation at a time, continuity of knowledge and effort is made possible.

This approach came to the attention of CCNR through the efforts of Jim Werner, who collaborated with Robert Del Tredici – under the auspices of the U.S. Department of Energy – to document the daunting multibillion dollar waste management and decontamination problems afflicting the US nuclear weapons complex. Their collaboration resulted in three important DOE publications: Closing the Circle on the Splitting of the Atom, Linking Legacies, and From Cleanup to Stewardship – all dealing with formidable nuclear waste management challenges.

Rolling Stewardship is discussed in a 1999 publication of the U.S. National Environmental Policy Institute entitled "Rolling Stewardship: Beyond Institutional Controls: Preparing Future Generations for Long-Term Environmental Cleanups", produced as part of the "How Clean is Clean?" project. It can be found on-line at: http://tinyurl.com/ljbwdv5

Examples of Rolling Stewardship

The Joint Review Panel has asked CCNR to provide examples of Rolling Stewardship. This document is a response to that request. Evidently, examples are not easy to come by. Never before has so much toxic material been created by any human enterprise, so the challenge of safely managing it over long time spans has never occurred. A new situation requires new and creative approaches. Like nuclear power itself, Rolling Stewardship is a relatively new concept.

Nevertheless CCNR has succeeded in identifying examples in the nuclear field where the failure of the "disposal" concept has led to a more responsible approach – in one way or another, some version of Rolling Stewardship. One might call this Rolling Stewardship by default – not planned ahead of time, but implemented as a fall-back position after misguided disposal efforts have backfired, causing extensive environmental impacts (e.g. Port Hope, Chalk River, Elliot Lake, Uranium City).

It is encouraging to note however that nuclear waste managers (and others) are increasingly adopting the philosophy of Rolling Stewardship – at least for a period of a few centuries at a time – although they do not refer to it as such.

CCNR has been pleased to respond to the Panel's request. However, the burden of proof regarding the safe management of nuclear waste should not be on us, the citizens, but on the nuclear corporations and their government owners who continue to mass produce this waste on a daily basis without having developed any proven reliable method to eliminate it or isolate it forever from the environment of living things.

CCNR calls on the Joint Review Panel to require OPG to provide examples of successful abandonment schemes involving long-lived persistent toxins – schemes that can be proven to have worked to protect humans and the environment for at least one or more centuries. CCNR believes that none exist. In the absence of such evidence, OPG's project for a DGR and a DUD at Kincardine, predicated on abandonment of the waste, ought to be rejected. Rolling Stewardship is the responsible course of action.

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

Maids of Muslyumovo

Women from the village of Muslyumovo in Chelyabinsk watch Western scientists measure radiation in the Techa River by their town. The Chelyabinsk reactor, upstream, made plutonium for the first Soviet atomic bombs. From 1949 to1953 the plant dumped liquid high-level waste directly into the Techa – a crude attempt at radioactive waste disposal. Forty years later, these women are discovering that the illnesses all around them are related to the radioactive contamination that was dumpoed in their river.
Village of Muslyumovo, Chelyabinsk, Russia. 17 March 1991

CONTEXT

The Nature of the Waste

At first, OPG planned to put into its Deep Geologic Depository only radioactive wastes that are low-level and short-lived. Then OPG threw caution to the winds, announcing that it would include many more varieties of waste – objects that are far more radioactive and incredibly longer-lived – such as refurbishment wastes.

Refurbishment wastes include all the intensely radioactive metallic components that make up the primary cooling system – 7 to 9 kilometers of small-diameter pipes that conduct superheated water from the core of the reactor to several nuclear boilers.

The nuclear boilers, called steam generators, are the furthest away from the core. They are a lot less radioactive than the pipes in the core. Nevertheless, each steam generator has thousands of narrow tubes inside , and these tubes become heavily contaminated during decades of use. They are all part of the refurbishment wastes.

1) Many radioactive materials in refurbishment wastes are extremely long-lived.

The CNSC list of radionuclides contaminating the internal pipes of a used steam generator from the Bruce plant [See Appendix A] includes 8 substances with a half-life of over a million years, 13 with a half-life of over 100,000 years, 19 with a half-life of over 1000 years, and 21 with a half-life of over 100 years.

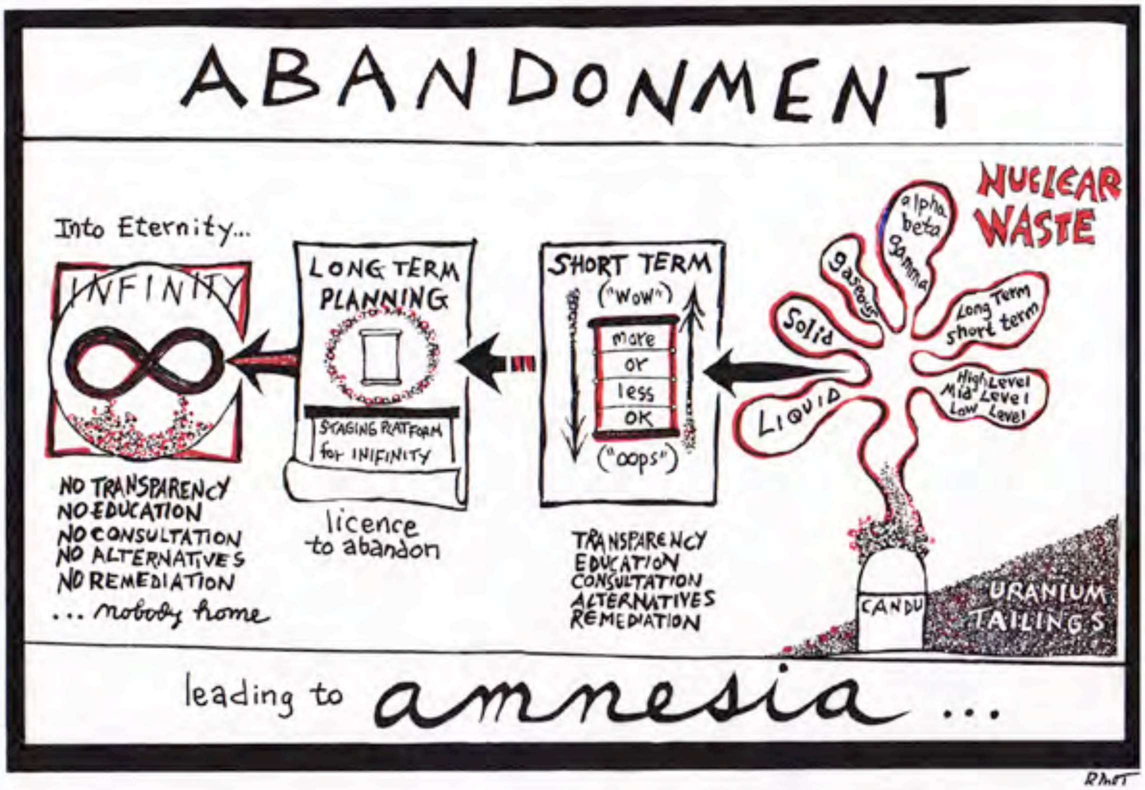
2) Many of these waste materials are extremely radiotoxic even in minute amounts.

The maximum permissible body burden of plutonium-239 for an atomic worker is 0.7 micrograms. Inside each used steam generator there are about 2.3 grams of plutonium-239. [See Appendix B.] Counting 128 steam generators from the Bruce NPP alone, there is enough plutonium-239 from the steam generators alone to overdose more than 420 million atomic workers. This is not counting the additional plutonium contamination from thousands of pressure tubes and feeder pipes. Since plutonium-239 has a 24,000 year half-life, the danger will not be significantly reduced by the time the steam generator tubes have completely disintegrated and released their inventories of plutonium.

3) NWMO acknowledges that dilution is not a solution to the nuclear waste problem.

Frank King of the Nuclear Waste Management Agency stated in his testimony to the Joint Review Panel, "Dilution simply doesn't work with nuclear material. It's out." Just as there is no safe level of cigarette smoking, and no safe level of asbestos, so too there is no safe level of exposure to atomic radiation. It is a characteristic of all carcinogenic and mutagenic substances, such as radionuclides, that even small exposures can cause deleterious health effects (i.e. cancers) if a large enough population is exposed. Since the Great Lakes provide drinking water for 40 million people, diluting long-lived radioactive poisons in Lake Huron will ensure that a very large number of people will be exposed for a very long time.

Since there is no practical method known to science that can destroy any of these radioactive wastes or render them harmless, sequestering them is essential.



Abandon (n) : to cease to support or look after; to desert.
Disposal (n): the process of throwing away or getting rid of something.
Management (n): the process of dealing with or controlling something.

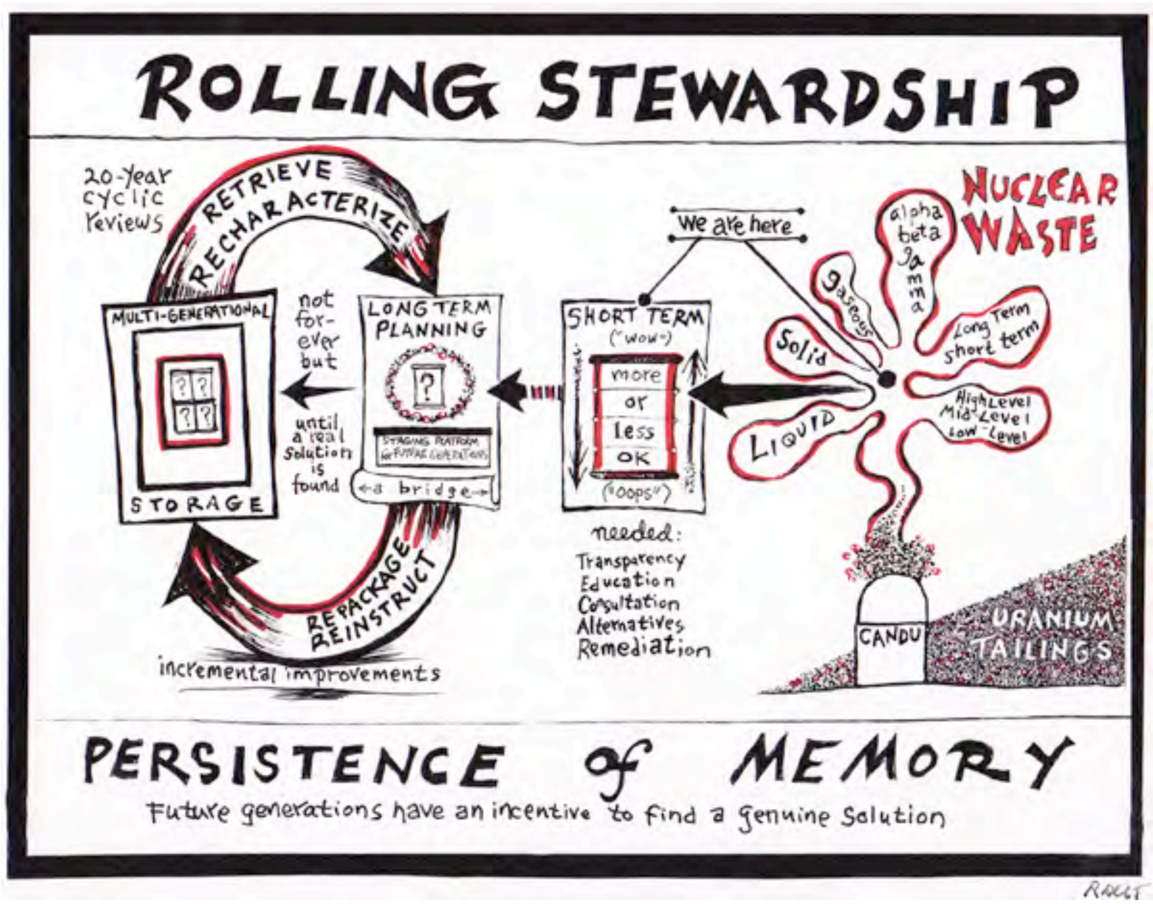
The nuclear industry and its government owners are responsible for the long-term management of nuclear waste. That means dealing with the waste and controlling it so that it does not endanger the health and safety of people or the environment.

To abandon nuclear waste, as proposed by OPG in its current proposal to build a Deep Geological Repository (DGR) beside Lake Huron, is to cease to look after it. As such it is a breach of governments' fundamental moral and legal obligations to society.

> *"The DGR Project includes the site preparation and construction, operations, decommissioning, and abandonment and long-term performance of the DGR."*
>
> *EIS Volume 1, second paragraph, Executive Summary*

Abandonment is intended to dispose of nuclear waste – to get rid of it by throwing it away. But no one knows how to truly get rid of long-lived nuclear waste or any other persistent toxic material in this manner. A corporation may rid itself of toxic waste but only at the risk of burdening others – present or future generations – with the obligation of coping with the waste or living with the harmful consequences.

Abandonment eventually leads to amnesia. Future generations have no adequate knowledge or resources to deal with leaks that may go undetected for long periods.



Realizing that there is as yet no genuine solution to the nuclear waste problem – we do not know how to destroy this waste or render it harmless – the only responsible alternative to abandonment is Rolling Stewardship. There is a growing awareness on the part of those who have struggled with this problem that this is the way to go.

> *"The word "disposal" has come to mean permanence and irretrievability in the minds of the public, and that raises questions about our stewardship of the waste. For that reason we do not use the word disposal."*
>
> *NWMO, Choosing A Way Forward, Final Study (2005), Page 21*

Nuclear waste remains harmful for unimaginably long periods of time. Until the waste can be eliminated, it must be managed on a multigenerational basis. This implies continual monitoring and periodic retrieval and repackaging (e.g. 50 – 100 years).

Rolling Stewardship implies persistence of memory : the accurate transmission of information and the transfer of responsibility from one generation to the next. For example, there could be a ceremonial "changing of the guard" every 20 years, accompanied by a thorough refamiliarization with & recharacterization of the waste.

Rolling Stewardship will ensure that leakages can be rapidly detected and corrected. It will also provide a constant incentive to improve containment and find a solution to the waste problem. But it requires meticulous planning and commitment to succeed.

The Concept of Abandonment	The Concept of Rolling Stewardship
1. Humans have never permanently disposed of anything.	1. Humans can contain waste securely for decades at a time.
2. Assumes a permanent solution to waste problem exists.	2. Recognizes a solution to the problem does not yet exist.
3. Monitoring the waste ceases after abandonment.	3. Continual monitoring of waste is essential.
4. Retrieval is difficult or impossible.	4. Retrieval is anticipated and actively planned for.
5. Containers will inevitably disintegrate.	5. Periodic repackaging is an integral part of the process.
6. If leakage occurs timely corrective action is not likely.	6. If leakage occurs timely corrective action will be taken.
7. Abandonment will eventually result in amnesia.	7. Rolling Stewardship is based on persistence of memory.
8. Difficulty in communicating to unknown future societies.	8. Information is readily transmitted to the next generation.
9. No intention to truly solve the problem of nuclear waste.	9. Ongoing reminder that the problem remains to be solved.

The concepts of abandonment and disposal are intimately related. According to the IAEA "disposal" means that there is no intention to retrieve the waste in the future – although such retrieval may, with difficulty, be possible; the waste is abandoned.

When disposal attempts fail – as in Port Hope Ontario, the Asse-II salt mine in Germany, the Love Canal in New York State, or the US DOE's "Pit 9" in Idaho – cleaning up and consolidating the waste is often exceedingly costly & difficult because of lack of documentation, failed packaging, and damage already done.

Ironically, the end result of failed disposal is usually some form of Rolling Stewardship – by default, not by intent. Had Rolling Stewardship been instituted from the start, the damage, difficulties and cost would have been greatly reduced.

When abandonment of a repository occurs, the repository becomes, de facto, a dump. Even if the repository has been well managed, the dump will not be. No matter how well designed a large nuclear power reactor might be, it would be foolish and irresponsible to licence it for operation, start it up and then abandon it. Yet that's what OPG hopes to do in the case of the Deep Underground Dump (DUD).

The pyramids of Egypt are 5,000 years old. The Great Lakes did not exist 15,000 years ago. But the half-life of plutonium-239 is 24,000 years, and in the DUD it gradually changes into uranium-235, with a half-life of 700 million years.

Science is unable to make reliable predictions over hundreds of thousands of years, since the mathematical predictions can't be verified against experience. As the rollout of ObamaCare has shown in the USA, computer bugs can often go undetected.

Geology is a descriptive science, not a predictive one. Besides, it is impossible to place wastes in an undisturbed geological formation without disturbing it.

Canadians have much expertise in mining – but a mine is for taking things out, not putting them in. And deserted mines always flood. No one knows how to put a rock formation back together again so that it returns to its original strength and integrity.

Example of Failed Abandonment:

AECL's "Geologic Disposal" Concept

In 1978 the Governments of Canada and Ontario signed an agreement to finance a 15-year research effort to "verify" the concept of geologic disposal of high-level nuclear waste (a.k.a. irradiated nuclear fuel) in a Deep Geologic Repository (DGR). This project was the grandfather of OPG's current proposal for a DGR at Kincardine.

The costly and ambitious AECL study – it involved constructing an Underground Research Laboratory in Manitoba – was precipitated by a flurry of reports that advocated a moratorium on new nuclear reactors unless a solution to the waste problem could be demonstrated. Evidently, the nuclear industry was under the gun.

Both levels of government had been assured by nuclear proponents in their employ that nuclear waste disposal is not a technical problem but merely a public relations problem. Abandoning the waste in a deep geological repository was portrayed as the solution before any ground was broken or evidence was collected. AECL's mission was to "verify", not to "explore" or "test", that hypothesis – not exactly objective.

The results of AECL's research was compiled in a multi-volume Environmental Impact Study (EIS) on the "Concept for Disposal of Canada's Nuclear Fuel Waste" (AECL-10711, COG-93-1). Then came a remarkable 10-year Environmental Review by the Seaborn Panel, with public hearings held in five different provinces.

In its final report, the Seaborn Panel stated that

> *"the AECL concept for deep geological disposal has not been demonstrated to have broad public support. The concept in its current form does not have the required level of acceptability to be adopted as Canada's approach for managing nuclear fuel wastes." '*
>
> *Executive Summary, Seaborn Panel Report*

It appears that the sticking point for the Panel may have been the thorny question of abandonment, expressed by AECL through its use of the word "disposal". AECL carried out a detailed post-closure assessment to justify its thesis that abandoning the waste in the DGR, by closing, backfilling and sealing the underground chambers and shaft, would guarantee safety for at least 10,000 years.

But the Scientific Review Group set up to advise the Seaborn Panel on technical aspects of the EIS was unanimous in rejecting AECL's "post-closure assessment". [See Appendix C] There were just too many arbitrary assumptions at work.

In the Executive Summary of the Seaborn Panel's Report, the word "disposal" is never used – except to indicate that AECL uses that word and the government also. The section entitled "Future Steps" refers to the "management" of nuclear wastes, without a single mention of the word "disposal". [See Appendix D.]

And to top it all off, the Seaborn Panel recommends that "developing and comparing options for managing nuclear fuel wastes" should be an important next step. Then it concludes the Executive Summary by saying "If the AECL concept is chosen as the most acceptable option after implementation of the steps recommended above…." Twenty years of effort, $750 million spent – and the result is still uncertainty.

The Seaborn Panel simply could not bring itself to endorse AECL's concept of abandonment as an acceptable strategy for nuclear fuel waste management. When the Chrétien government responded to the Seaborn Panel's Report by passing the Nuclear Fuel Waste Act, a newly formed NWMO took the lesson of the Seaborn Report to heart and expunged the word "disposal" from its vocabularly.

This entire 20-year exercise – from 1978 to 1998 – cast serious doubts on the validity of the concept of abandonment as an acceptable strategy for nuclear waste.

Irretrievable High Level Waste Disposal Test Shaft

This granite chamber lies 500 meters beneath the surface of the Great Canadian Shield. It is a test shaft sunk by Atomic Energy of Canada Limited to investigate pre-Cambrian rock as a possible permanent repository for high-level nuclear waste.

Underground Research Laboratory, Lac du Bonnet, Manitoba. 15 September 1986.

An Example of Rolling Stewardship:

“Adaptive Phased Management”

The Nuclear Waste Management Organization (NWMO) has proposed a strategy for dealing with Canada’s nuclear fuel wastes called “Adaptive Phased Management”. The strategy was adopted by the Government of Canada in 2007 and is described in the 2005 NWMO Final Study entitled “Choosing A Way Forward” [Final Study].

NWMO’s Adaptive Phased Management includes a recipe for Rolling Stewardship for the next 100 to 300 years. If a single generation is counted as 20 years, then the NWMO strategy prescribes Rolling Stewardship for at least 5 to 15 generations.

In an illustrative implementation schedule [page 27] NWMO assigns 20 years to site a central storage facility, 10 more years to build a characterization facility, 30 years for transportation of used fuel to the central facility, another 30 years for emplacement of irradiated nuclear fuel in deep underground chambers, followed by extended monitoring for up to 300 years. That’s almost 20 generations.

The question arises: if Rolling Stewardship can work for 300 years, why not for another 300 years if need be? And then for another 300 years if the need contrinues? That’s close to a millennium.

In Choosing A Way Forward, NWMO explicitly refrains from using the word “disposal” except in the context of the specific AECL proposal for abandoning the nuclear fuel waste for eternity in a DGR specifically built for that purpose:

> *“For purposes of this report we have defined storage as a method of managing the waste in a manner that allows access under controlled conditions for retrieval or future activities -- while disposal is conclusive without any intention of retrieval or further use…. Note that the only time we refer to disposal as a possible Canadian approach is in reference to [the] specific AECL proposal.” Final Study, page 21*

NWMO clearly envisages the eventual closure and sealing (“decommissioning”) of its underground facility at some future date, but it is clearly conditional:

> *“Once a societal decision was made and the necessary approvals were obtained, decommissioning would commence and all underground access tunnels and shafts would be backfilled and sealed.” Final Study, page 27.*

NWMO does not presuppose that such permission has been granted already. Nor does NWMO assert that abandonment will be regarded as acceptable. It is for future generations to judge the matter, based on knowledge gained and technological advances made, whether to abandon the waste, or to implement a more satisfactory containment strategy, or to continue searching for a genuinely permanent solution.

Rolling Stewardship by Default:

The Port Hope Saga

In the early years of Canada's uranium / radium history, large volumes of radioactive wastes from the Eldorado refinery in Port Hope Ontario were dumped into the harbor and into several of the beautiful ravines around town. These were crude efforts at disposal, for there was certainly no intention to retrieve these wastes at the time.

During the World War II Atomic Bomb Project, many of these wastes were processed to extract the leftover uranium, the key element needed for all nuclear weapons. Before the war there had been no market for uranium, so the refinery was built to extract radium – a naturally occurring radioactive byproduct of uranium that was the most valuable substance on Earth during the first half of the twentieth century.

But in the mid-1970s it became clear that hundreds of thousands of tonnes of dangerous radioactive material had been carelessly dumped in ways that were completely irresponsible. Hundreds of homes and some schools had been built using radioactive material that posed serious long-term health risks for the inhabitants.

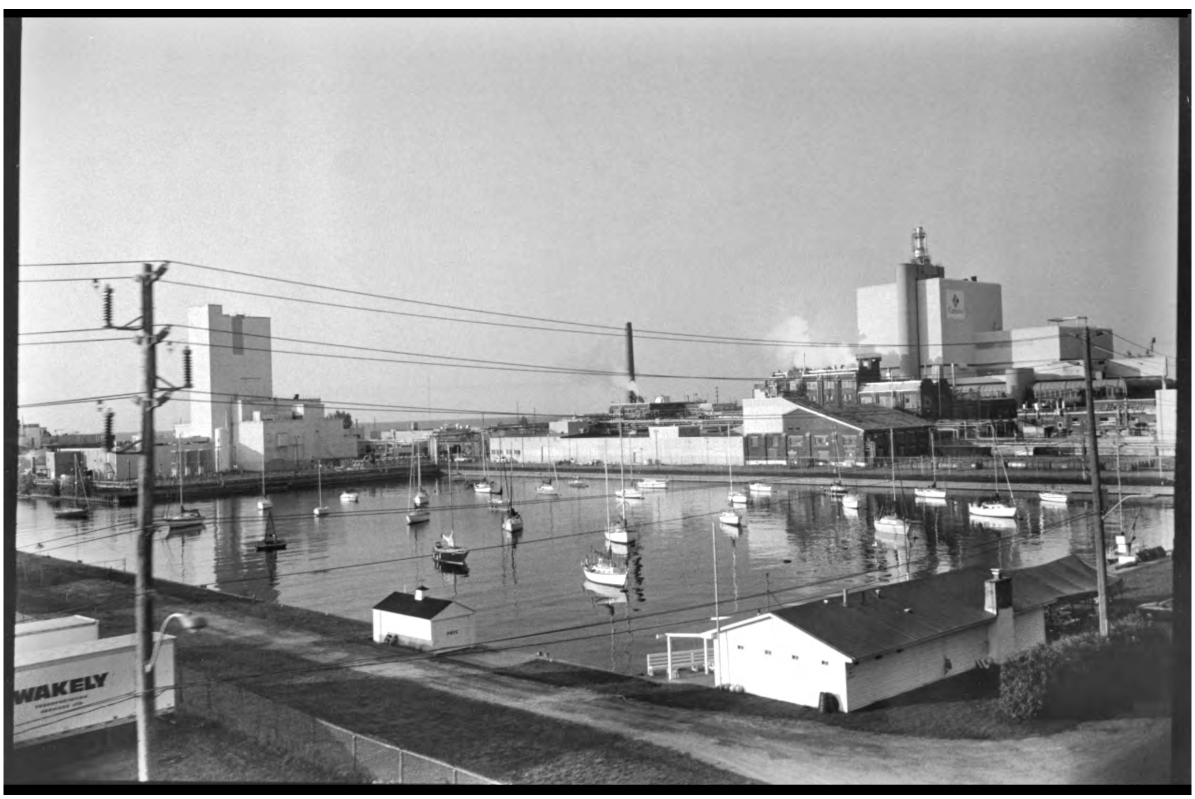
In the 1980s a federal agency was formed, the Siting Task Force, with a specific mandate to find a home for some 800,000 tonnes of long-lived low-level radioactive wastes from Port Hope. The Task Force spent three years trying to find a willing host community somewhere in Ontario to accept these radioactive wastes in exchange for economic benefits, but they came up empty-handed.

Radiation Warning Sign, Welcome Dump, Port Hope, Ontario

In the 1990s, AECL's Low-Level Radioactive Waste Management Organization was formed, and a few years later plans were made to remediate the Town of Port Hope by excavating and consolidating all of the radioactive waste material that had been carelessly strewn around town. Since no other Ontario community is willing to accept these wastes, plans have been made to construct a long-term waste facility at the Welcome dump site, located on Marsh Road just north of the town of Port Hope.

The new Welcome facility is designed to last for 500 years. But the radium-bearing wastes will continue to generate radon gas for thirty times as long, since radium-226 has a half-life of 1600 years. Evidently, Port Hope should be embarking on a long-term exercise in Rolling Stewardship. The only question is, will it be planned and executed smoothly on an intergenerational basis? Or will it be characterized by neglect and degenerate into yet another radioactive fiasco in the future?

The cleanup of the Town of Port Hope is currently underway. The cost has spiraled upwards from $800 million to $1,800 million. To extract radioactive sediments from the Port Hope harbor, vertical steel plates will be used to line the sides and then the harbour will be dredged. In other parts of town large volumes of contaminated soil must be dug up and packaged as radioactive waste. Had the principle of Rolling Stewardship been applied from the beginning, the damage would never have got out of hand – the environmental impacts, the social distress, the runaway costs, all of these factors would have been minimized by Rolling Stewardship.



Port Hope Harbour, with the largest uranium conversion facility in the world

Conclusion

The Canadian Coalition for Nuclear Responsibility encourages the Joint Review Panel to make it clear that it cannot approve OPG's proposal to abandon Ontario's inventory of low and intermediate level nuclear waste close to Lake Huron.

Since OPG is determined to make the abandonment of nuclear waste an integral part of its DGR project, CCNR urges the Panel to reject the proposal in its entirety.

The nuclear industry worldwide is beginning to realize it needs not only a regulatory licence to manage its wastes; it also needs a social licence. OPG's plan to abandon nuclear wastes by the Great Lakes is, for millions of people on both sides of the border, unacceptable. No social licence is forthcoming for this scheme.

There are so many uncertainties associated with the long term future that the Seaborn Panel's *Scientific Review Group* could not endorse abandonment of nuclear waste in a DGR. This Panel should do likewise for similar reasons.

The NWMO has carefully avoided forcing a decision today on the future prospect of abandoning nuclear waste. CCNR believes this Panel should do the same.

OPG has made it clear that current waste storage practices can be extended for decades. Let them do so. With continual monitoring and dramatic improvements in technology, greater security can be provided at less cost than the proposed DGR.

Hanford Plutonium Finishing Plant, Hanford, Washington. 11 July 1994.

***Appendix A** : Radioactive contaminants in used nuclear steam generators*

*Here is a **partial** list of radioactive contaminants inside a used steam generator from one of the Bruce reactors. The amount of radioactivity is expressed in becquerels per cubic metre; one becquerel corresponds to one radioactive disintegration every second. (Source: OPG)*
http://www.nwmo.ca/uploads_managed/MediaFiles/539_ReferenceLowandIntermediateWasteInventoryfortheDGR.pdf (p. 50)

For Scientists/Engineers			*For Citizens/ Decision Makers*		
Symbol	Half-Life	Amount	Name	Half-Life	Amount
Ag 108	1.3E+02	2.3E+02	Silver-108	130 y	230
Am-241	4.3E+02	5.9E+07	Americium-241	430 y	59 000 000
Am-243	7.4E+03	3.8E+04	Americium-243	7 400 y	38 000
C-14	5.7E+03	7.6E+07	Carbon-14	5 700 y	76 000 000
Cl-36	3.0E+05	1.4E+04	Chlorine-36	300 000 y	14 000
Cm-244	1.8E+01	1.4E+07	Curium-244	18 y	14 000 000
Co-60	5.3E+00	1.2E+09	Cobalt-60	5.3 y	1 200 000 000
Cs-134	2.1E+00	1.9E+06	Cesium-134	2.1 y	1 900 000
Cs-135	2.3E+06	2.2E+01	Cesium-135	2 300 000 y	22
Cs-137	3.0E+01	2.2E+07	Cesium-137	30 y	22 000 000
Eu-152	1.3E+01	1.8E+06	Europium-152	13 y	1 800 000
Eu-154	8.8E+00	1.6E+07	Europium-154	8.8 y	16 000 000
Eu-155	5.0E+00	3.0E+07	Europium-156	5 y	30 000 000
Fe-55	2.7E+00	5.8E+09	Iron-55	2.7 y	5 800 000 000
I-129	1.6E+07	6.3E+00	Iodine-129	16 000 000 y	6.3
Nb-94	2.0E+04	2.9E+05	Niobium-94	20 000 y	290 000
Ni-59	7.5E+04	2.0E+05	Nickel-59	75 000 y	200 000
Ni-63	9.6E+01	2.9E+07	Nickel-63	96 y	29 000 000
Np-237	2.1E+06	1.8E+03	Neptunium-237	2 100 000 y	1 800
Pu-238	8.8E+01	1.0E+07	Plutonium-238	88 y	10 000 000
Pu-239	2.4E+04	1.2E+07	Plutonium-239	24 000 y	12 000 000
Pu-240	6.5E+03	1.7E+07	Plutonium-240	6 500 y	17 000 000
Pu-241	1.4E+01	5.5E+08	Plutonium-241	14 y	550 000 000
Pu-242	3.8E+05	1.7E+04	Plutonium-242	380 000 y	17 000
Ru-106	1.0E+00	8.4E+08	Ruthenium-106	1 y	840 000 000
Sb-125	2.8E+00	2.1E+07	Antimony-125	2.8 y	21 000 000
Se-79	1.1E+06	7.6E+01	Selenium-79	1 100 000 y	76
Sm-151	1 9E+01	7.6E+01	Samarium-151	19 y	76
Sn-126	2.1E+05	1.2E+02	Tin-126	210 000 y	120
Sr-90	2.9E+01	1.8E+07	Strontium-90	29 y	18 000 000
Tc-99	2.1E+05	2.8E+03	Technetium-99	210 000 y	2 800
U-234	2.5E+05	1.9E+04	Uranium-234	250 000 y	19 000
U-235	7.0E+08	3.2E+02	Uranium-235	700 000 000 y	320
U-236	2.3E+07	3.6E+03	Uranium-236	23 000 000 y	24 000
U-238	4.5E+09	2.4E+04	Uranium-238	4 500 000 000 y	24 000
Zr-93	1.5E+06	3.8E+02	Zirconium-93	1 500 000 y	380
TOTALS					
Long half-lives only		**8.7E+09**		**(long-lived)**	**8 700 000 000**
Including short half-lives		**1.6E+10**		**(all radionuclides)**	**16 000 000 000**

According to this OPG document (see the last 2 lines), there are over eight BILLION radioactive disintegrations taking place every second in each cubic metre, if we consider only the long-lived radioactive contaminants. Each disintegration releases an alpha particle, a beta particle, or a gamma ray; so there are more than eight billion of these subatomic projectiles emitted every second. That's more than 28 trillion per hour, and over 245 quintillion per year. *[OPG = Ontario Power Generation]*

In particular, there are five plutonium isotopes found in the steam generators. There are about 580 million alpha rays given off each second, in each cubic metre, from these five plutonium isotopes alone. If the steam generators are just stored on-site as radioactive waste for one thousand years, these plutonium isotopes will still be giving off about 30 million alpha particles per second, per cubic metre.

Gordon Edwards, Ph.D

Appendix B. Plutonium in 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 radioactive material listed is estimated by CNSC staff.*

RADIONUCLIDE		***MASS***	
Name of Isotope (with Atomic Mass)	Half-Life (years)	Unit 1 (grams radioactive material)	Unit 2
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
Plutonium-238	*88 y*	*0.007507*	*0.004703*
Plutonium-239	*24 000 y*	*2.124977*	*2.471769*
Plutonium-240	*6 500 y*	*0.827304*	*0.957105*
Plutonium-241	*14 y*	*0.021309*	*0.030809*
Plutonium-242	*380 000 y*	*0.048762*	*0.056317*
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
TOTALS			
Long-lived (> one year half-life)		**3.416108**	**3.787315**
Mass of plutonium isotopes only		**3.029859**	**3.520703**
Percent plutonium		**88.7%**	**93.0%**
TOTAL MASS			
(Source: CNSC document		*CMD-10-H19B)*	

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 from Units 1 and 2 (8 from each) the total mass of radioactive material is estimated to be about 57.6 grams, of which 52.4 grams is plutonium. So the 5 isoptopes of plutonium make up 91.0 percent of the mass of radioactive material in all 16 vessels.

Plutonium is extremely dangerous even in minute quantities. For example, the maximum permissible "body burden" of plutonium-239 for an atomic worker (e.g. someone working in the U.S. 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 about doubled.

Plutonium isotopes also have very long half-lives, ranging from decades to hundreds of thousands of years. This means that anyleakage of these materials can pose long-lasting dangers.

- Gordon Edwards, Ph.D., November 8, 2010

An Evaluation of Atomic Energy of Canada Limited's "Environmental Impact Statement on the Concept for Disposal of Canada's Nuclear Fuel Waste"

(AECL-10711, COG-93-1)

by the *Scientific Review Group (SRG)*

Advisory to the Federal Environmental Assessment Review Panel

Taken from the Executive Summary

Summary and Conclusions

The AECL postclosure reference case study raises problems. In addition to the fact that it is site specific and has not been demonstrated to be applicable to various other potential fuel waste repository sites in the Canadian Shield**, there are problems with unclear objectives, with methods of analysis, and with the validity of the results of the postclosure reference case study itself.**

The assessment is based on predictions from numerical models. The SRG notes with concern that reliance on SYVAC has inhibited the introduction or use of more modern and flexible software and up-to-date data and has, to a degree, undermined the effectiveness of the assessments.

The SRG concludes that the results of the postclosure performance assessment are not reliable because:

- the reference case is too narrow a representative of the disposal concept;
- the conceptual framework for the reference case model is flawed;
- the choice of input parameteres, initial and boundary conditions, and source terms for the model are not satisfactory;
- the uncertainty analysis is not convincing; and
- the modelling of the exposure of humans and other living organisms to contaminants passing through the biosphere does not accomodate the likelihood of environmental or ecological changes over a 10,000 year period.

On the basis of these shortcomings, and its review of the detailed descriptions of the concept presented in the EIS and the supporting primary reference documents, **the SRG disagrees with AECL's conclusion** that:

> *"The methodology to evaluate the safety of a disposal system against established safety criteria, guidelines and standards has been developed and demonstrated to the extent reasonably achievable in a generic research program."*

Environmental Assessment Report on High Level Waste Disposal Concept

EXECUTIVE SUMMARY

In a 1978 joint statement, the governments of Canada and Ontario directed Atomic Energy of Canada Limited (AECL) to develop the concept of deep geological disposal of nuclear fuel wastes. A subsequent joint statement in 1981 established that disposal site selection would not begin until after a full federal public hearing and approval of the concept by both governments.

In September 1988, the federal Minister of Energy, Mines and Resources referred the concept, along with a broad range of nuclear fuel waste management issues, for public review. He made this referral under the federal Environmental Assessment and Review Process Guidelines Order. On October 4, 1989, the federal Minister of the Environment appointed an independent environmental assessment panel to conduct the review. A copy of the Terms of Reference for the review is included in Appendix A, and biographies of the eight panel members are included in Appendix B.

The panel's mandate was unusual compared to that of any other federal environmental assessment panel in that it was asked

- to review a concept rather than a specific project at a specific site;
- to review a proposal for which the implementing agency was not identified;
- to establish a scientific review group of distinguished independent experts to examine the safety and scientific acceptability of the proposal;
- to review a broad range of policy issues; and
- to conduct the review in five provinces.

AECL describes its concept as a method for geological disposal of nuclear fuel wastes in which

- the waste form is either used Canada Deuterium Uranium (CANDU) fuel or the solidified high-level wastes from reprocessing;
- the waste form is sealed in a container designed to last at least 500 years and possibly much longer;
- the containers of waste are emplaced in rooms in a disposal vault or in boreholes drilled from the rooms;
- the disposal rooms are between 500 and 1000 metres below the surface;
- the geological medium is plutonic rock of the Canadian Shield;
- each container of waste is surrounded by a buffer;
- each room is sealed with backfill and other vault seals; and
- all tunnels, shafts and exploration boreholes are ultimately sealed in such a way that a disposal facility would be passively safe – that is, long-term safety would not depend on institutional controls.

Such a facility would cost an estimated $8.7 billion to $13.3 billion in 1991 dollars, depending on the amount of waste to be disposed of.

The Panel conducted its review in Saskatchewan, Manitoba, Ontario, Quebec and New Brunswick. To develop guidelines to help AECL prepare an environmental impact statement (EIS), the Panel held scoping meetings in autumn 1990 in 14 communities. It also held a workshop on Aboriginal issues and met with members of Canadian Student Pugwash. The Panel then prepared draft guidelines, released them for public comment in June 1991, and issued them in final form on March 18, 1992. On October 26, 1994, AECL submitted an EIS, supported by nine primary reference documents. The period for public review of the EIS began on November 8, 1994, and ended on August 8, 1995.

Public hearings were held in 16 communities over three phases beginning March 11, 1996 and ending March 27, 1997. Phase I focused on broad societal issues related to managing nuclear fuel wastes; Phase II focused on the safety of the AECL concept from a technical viewpoint; and Phase III focused on the public's opinions of the safety and acceptability of the concept. During all three phases, the Panel heard from a total of 531 registered speakers and received 536 written submissions, as listed in Appendix F. Participants were also allowed to submit brief closing statements in writing by April 18, 1997. The Panel considered all written and oral information received in the period from its appointment to the end of the hearings, as well as the closing statements, in preparing this report. A detailed chronology of the panel's activities can be found in Appendix E.

Among other activities, the Terms of Reference directed the Panel

- to examine the criteria by which the safety and acceptability of a concept for long-term waste management and disposal should be evaluated; and
- to prepare a final report addressing whether AECL's concept is safe and acceptable or should be modified, and the future steps to be taken in managing nuclear fuel wastes in Canada.

CRITERIA FOR SAFETY AND ACCEPTABILITY

The Panel examined the criteria by which the safety and acceptability of any concept for long-term waste management should be evaluated (Chapter 4 of this report). In doing so, it came to the following key conclusions.

Key Panel Conclusions

- Broad public support is necessary in Canada to ensure the acceptability of a concept for managing nuclear fuel wastes.
- Safety is a key part, but only one part, of acceptability. Safety must be viewed from two complementary perspectives: technical and social.

On this basis, the Panel defined the safety and acceptability criteria as follows:

To be considered acceptable, a concept for managing nuclear fuel wastes must

- a) have broad public support;
- b) be safe from both a technical and a social perspective;
- c) have been developed within a sound ethical and social assessment framework;

- d) have the support of Aboriginal people;
- e) be selected after comparison with the risks, costs and benefits of other options; and
- f) be advanced by a stable and trustworthy proponent and overseen by a trustworthy regulator.

To be considered safe, a concept for managing nuclear fuel wastes must be judged, on balance, to

- a) demonstrate robustness in meeting appropriate regulatory requirements;
- b) be based on thorough and participatory scenario analyses;
- c) use realistic data, modelling and natural analogues;
- d) incorporate sound science and good practices;
- e) demonstrate flexibility;
- f) demonstrate that implementation is feasible; and
- g) integrate peer review and international expertise.

Safety and Acceptability of the AECL Concept

After applying these criteria to the AECL disposal concept, the Panel arrived at the key conclusions listed below. The rationale for them, and an elaboration on the technical and social perspectives of safety, are documented in Chapter 5.

Key Panel Conclusions:

- From a technical perspective, safety of the AECL concept has been on balance adequately demonstrated for a conceptual stage of development, but from a social perspective, it has not.
- As it stands, the AECL concept for deep geological disposal has not been demonstrated to have broad public support. The concept in its current form does not have the required level of acceptability to be adopted as Canada's approach for managing nuclear fuel wastes.

Future Steps

The Panel considered the steps that must be taken to ensure the safe and acceptable long-term management of nuclear fuel wastes in Canada (in Chapter 6 of this report). It arrived at the following key recommendations.

Key Panel Recommendations

A number of additional steps are required to develop an approach for managing nuclear fuel wastes in a way that could achieve broad public support.

These include:

- issuing a policy statement on managing nuclear fuel wastes;
- initiating an Aboriginal participation process;
- creating a nuclear fuel waste management agency (NFWMA);
- conducting a public review of AECB regulatory documents using a more effective consultation process;

- developing a comprehensive public participation plan;
- developing an ethical and social assessment framework; and
- developing and comparing options for managing nuclear fuel wastes.

Taking into account the views of participants in our public hearings and our own analysis, we have developed the following basic recommendations to governments with respect to a management agency:

- that an NFWMA as described in Chapter 6 be established quickly, at arm's length from the utilities and AECL, with the sole purpose of managing and coordinating the full range of activities relating to the long-term management of nuclear fuel wastes;
- that it be fully funded in all its operations from a segregated fund to which only the producers and owners of nuclear fuel wastes would contribute;
- that its board of directors, appointed by the federal government, be representative of key stakeholders;
- that it have a strong and active advisory council representative of a wide variety of interested parties;
- that its purposes, responsibilities and accountability, particularly in relation to the ownership of the wastes, be clearly and explicitly spelled out, preferably in legislation or in its charter of incorporation; and
- that it be subject to multiple oversight mechanisms, including federal regulatory control with respect to its scientific-technical work and the adequacy of its financial guarantees; to policy direction from the federal government; and to regular public review, preferably by Parliament.

Until the foregoing steps have been completed and broad public acceptance of a nuclear fuel waste management approach has been achieved, the search for a specific site should not proceed.

If the AECL concept is chosen as the most acceptable option after implementation of the steps recommended above, governments should direct the NFWMA, together with Natural Resources Canada and the AECB or its successor, to undertake the following: review all the social and technical shortcomings identified by the Scientific Review Group and other review participants; establish their priority; and generate a plan to address them. The NFWMA should make this plan publicly available, invite public input, then implement the plan.

Additional and detailed recommendations on future steps are outlined in Chapter 6. Other aspects of the panel's mandate are dealt with in chapters 2 and 3 and in the appendices.

Appendix III

:

High Burnup Spent
Power Reactor Fuel

A Memorandum

by

Robert Alvarez

December 13, 2013

MEMORANDUM

Date: **December 13, 2013**

From: **Bob Alvarez**

Subject: **High Burnup Spent Power Reactor Fuel**

Introduction

Since the 1990's, U.S. reactor operators are permitted by the U.S. Nuclear Regulatory Commission (NRC) to effectively double the amount of time nuclear fuel can be irradiated in a reactor, by approving an increase in the percentage of uranium-235, the key fissionable material that generates energy. In doing so, NRC has bowed to the wishes of nuclear reactor operators, motivated more by economics than spent nuclear fuel storage and disposal.

Known as increased "burnup" this practice is described in terms of the amount of electricity in gigawatts (GW) produced per day with a ton of uranium.

Reactor fuel burnups have gradually increased on the average to ~50 GWd/t for Pressurized Reactors (PWR) and 43GWd/T for Boiling Water Reactors (BWR). [1] Projected burnups are estimated to increase. (See Figure 1) The current maximum peak burnup limit is 62MWd/t. Reactor operators would like to increase burnups to 75GWd/t..[2] As of 2008, the NRC allows reactors using uranium fuel to operate at the highest burnup rates of any country in the world.[3]

No adequate technical basis for the safe storage and disposal of high burnup spent nuclear fuel

While the move to high burnup in U.S. power reactors has improved the nuclear power sales, it remains a significant impediment to the safe storage and disposal of spent nuclear fuel. For more than a decade the problems and concerns associated with high burnup spent nuclear fuel have increased, while the resolution of these problems remains illusive. For instance:

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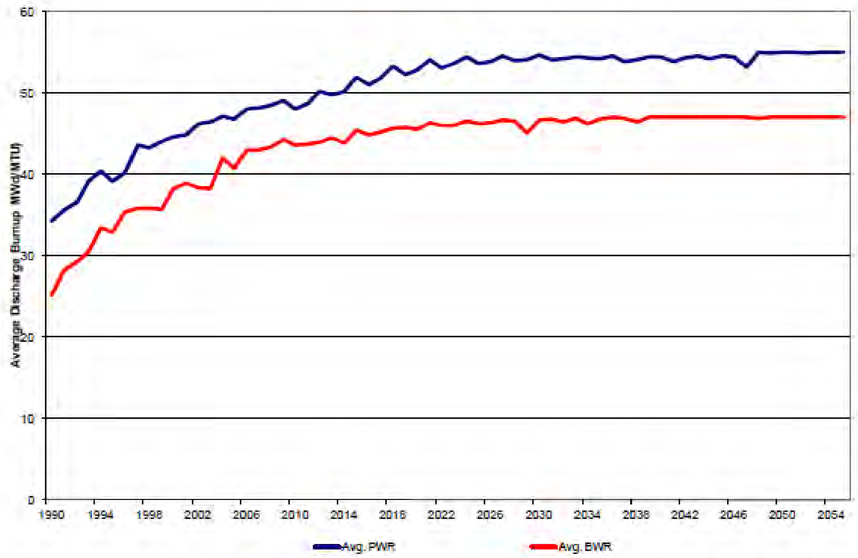
[1] E. Supko, Impacts Associated with Transfer of Spent Nuclear Fuel from Spent Fuel Storage Pools to Dry Storage After Five Years of Cooling, Revision 1, Electric Power Research Institute, August 2012.

[2] V. Jain, G. Cragnolino and L. Howard, A review Report on High Burnup Spent Nuclear Fuel Disposal Issues, Center for Nuclear Waste Regulatory Analyses, San Antonio, Texas, CNWRA 2004-08, September 2004, p.xv.

3 Erik Kolstad, Nuclear Fuel Behaviour in Operational Conditions and Reliability, Prepared for IPG meeting-Workshop on Fuel Behaviour, Argonne National Laboratory, September 2008, p. 10

Figure 1.Historical and Projected Average BWR and PWR Discharge Burnups
(Source: Supko/EPRI 2012)



- In 2000, several years after granting increased burnups for U.S. power reactors the U.S. Nuclear Regulatory Commission admitted, " There is limited data to show that the cladding of spent fuel with burnups greater than 45,000 MWd/MTU will remain undamaged during the licensing period." [4]

- In 2003 the Electric Power Research Institute concluded: "For the most part, the current licensing basis for dry storage of spent fuel is largely based on fuel examinations and dry storage performance demonstrations performed in the 1980s and 1990s. Spent fuel used in the dry storage performance demonstrations had discharge burnups of ~36 GWd/MTU, or less."[5]

- In 2010 researchers at Oak Ridge National Laboratory reported to the NRC that, "the majority of isotopic assay measurements available to date involve spent fuel with burnups of less than 40 GWd/MTU and initial enrichments below 4 wt % 235U, limiting the ability to validate computer code predictions and accurately quantify the uncertainties of isotopic analyses for modern fuels in the high burnup domain."[6]

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4 U.S. Nuclear Regulatory Commission, Standard Review Plan for Spent Fuel Dry Storage Facilities, Final Report NUREG-1567, March 2000. P. 6-15. http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1567/sr1567.pdf

[5] Electric Power Institute, Dry Storage Demonstration for High-Burnup Spent Nuclear Fuel Feasibility Study, September 2003, p.5-1.

[6] G. Ilas and I.C. Gauld, Analysis of Experimental Data for High-Burnup PWR Spent Fuel Isotopic Validation—Vandellós II Reactor, ORNL/TM-2009/32, p. 1. http://info.ornl.gov/sites/publications/files/Pub22621.pdf

- That same year the Nuclear Waste Technical Review Board reported that: "Only limited references were found on the inspection and characterization of fuel in dry storage, and they all were performed on low-burnup fuel after 15 years or less of dry storage. Insufficient information is available yet on high-burnup fuels to allow reliable predictions of degradation processes during extended dry storage, and no information was found on inspections conducted on high-burnup fuels to confirm the predictions that have been made."[7]

- In 2012, EPRI reported that: "R&D work will continue especially in concert with introduction of new cladding materials" [and] "R&D work will continue especially in concert with introduction of new cladding materials...[and a] Key question: Given what we learned, how does that knowledge support existing –or coming up with new– regulatory guidance?" [8]

- In 2012, the official publication of the National Academy of Engineering of the National Academy of Sciences raised similar concerns about the viability of high-burnup fuel by noting, "the technical basis for the spent fuel currently being discharged (high utilization, burnup fuels) is not well established… the NRC has not yet granted a license for the transport of the higher burnup fuels that are now commonly discharged from reactors. In addition, spent fuel that may have degraded after extended storage may present new obstacles to safe transport."[9]

Safety and economic concerns continue to mount.

EPRI pointed out in 2005 that: "*Failure to resolve, in a timely manner, regulatory issues associated with interim dry storage and transportation of high-burnup spent fuel would result in severe economic penalties and in operational limitations to nuclear plant operators.* [Emphasis added.]"[10]

Since that time, there remain several issues of concern that impact the storage and disposal of high-burnup spent nuclear fuel. With higher burn up, nuclear fuel rods undergo several potentially risky changes that include:

- Increasing oxidation, corrosion and hydriding of the fuel cladding. Oxidation reduces cladding thickness, while hydrogen (H3) absorption of the cladding to form a hydrogen-

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7 United States Nuclear Waste Technical Review Board, *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel, December 10, 201*0.

8 Albert Machiels, Electric Power Research Institute, High-Burnup – 10 Years Later, Used Fuel and HLW Management Technical Advisory Committee Washington, DC September 13, 2012

9 National Academy of Engineering, Managing Nuclear Waste, Summer 2012, pp 21, 31. http://www.nae.edu/File.aspx?id=60739

10 Electric Power research Institute, Application of Critical Strain Energy Density to Predicting High-Burnup Fuel Rod Failure, September 2005, P.vi.

based rust of the zirconium metal from the gas pressure inside the rod can cause the cladding to become brittle and fail;[11]

- Higher internal rod gas pressure between the pellets and the inner wall of the cladding leading to higher fission gas release. Pressure increases are typically two to three times greater.[12]
- During a power release at high burnup cladding can deform and fail.[13]
- Elongation or thinning of the cladding from increased internal fission gas pressure;[14]
- Structural damage and failure of the cladding caused by hoop (circumferential) stress; [15]
- Increased debris in the reactor vessel, damaging and rupturing fuel rods;[16]
- Cladding wear and failure from prolonged rubbing of fuel rods against grids that hold them in the assembly as the reactor operates (grid to rod fretting).[17]
- Oxidation of irradiated fuel pellets during extended storage.[18]
- A significant increase in radioactivity and decay heat in the spent fuel. [19]
- A potentially larger number of damaged spent fuel assemblies stored in pools[20]
- Upgraded pool storage with respect to heat removal and pool cleaning.[21]
- Requiring as much as 150 years of surface storage before final disposal. [22]
- Increased costs for disposal due to decay heat.[23]
- Potential repository criticality [24]
- Increased radiation doses following geologic disposal[25]

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11 U.S. Nuclear Regulatory Commission, Rulemaking Issue, Notation Vote, Memorandum from: R.W. Borchardt, Executive Director for Operations, Subject: Proposed Rulemaking – 10CFR 50.46c Emergency Core Cooling System Performance During Loss-of-Coolant Accidents (RIN 3150-AH42), SECY-12-0034, March 1, 2012, p. 2. http://www.nrc.gov/reading-rm/doc-collections/commission/secys/2012/2012-0034scy.pdf

12U.S. Nuclear regulatory Commission, Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants, October 2000, P. 45. http://pbadupws.nrc.gov/docs/ML0104/ML010430066.pdf

13 Stafano Caruso, c*haracterisation of high-burnup LWR fuel rods through gamma tomography*, ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE, April 2007.

14 Op cit ref. 12.

15 Ibid

16 International Atomic Energy Agency, Impact of High-Burnup Uranium Oxide and Mixed Uranium – Plutonium Oxide Water Reactor Fuel on Spent Fuel Management, IAEA Nuclear Energy Series, No.. NF-T-3.8, June 2011. P. 39. http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1490_web.pdf

17 Ibid.

18 Op Cit Ref. 7.

19 Op. cit ref. 16.

20 Ibid p. 51.

21 Ibid. p.1.

22 Zhiwen Xu, Mujid S. Kazimi and Michael Driscoll, Impact of High Burnup on PWR Spent Fuel Characteristics, Nuclear Science and Engineering, 151, 261-273 (2005), http://ocw.internet-institute.eu/courses/nuclear-engineering/22-251-systems-analysis-of-the-nuclear-fuel-cycle-fall-2005/readings/impact.pdf

23 Ibid.

24 Zhen Xu, Designing Strategies for Optimizing High Burnup in Pressurized Reactors, Massachusetts Institute of Technology, Department of Nuclear Engineering, January 2003.

25 Sitakanta Mohanty, Lynn Tipton, Razvan Nes, and David Pickett, High-Burnup of Spent Nuclear Fuel and Its Implications for Disposal Performance Assessments, Symposium on the Scientific Basis for Nuclear Waste Management XXXVI at the 2012 Materials Research Society Fall Meeting, Boston, Massachusetts, USA, November 25─30, 2012

- Swelling and closure of the pellet-cladding gap- increasing cladding stresses, creep and stress corrosion cracking of cladding in extended storage. [26]
- Embrittlement of cladding due to decreases in fuel temperatures during extended storage.[27]

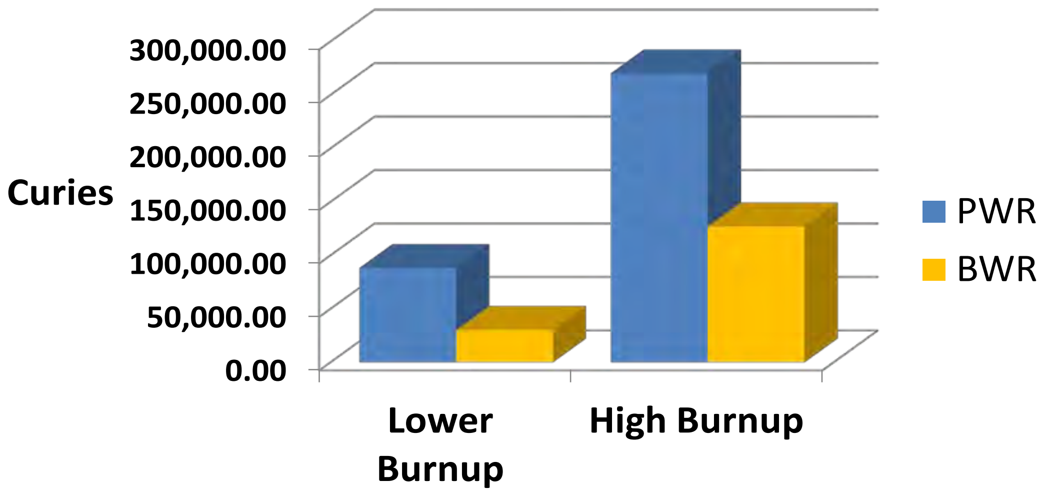
There is growing evidence that as a result of higher burn-ups nuclear fuel cladding cannot be relied upon as a primary barrier to prevent the escape of radioactivity, especially during dry storage. This has not been lost on the nuclear industry and staff of the NRC for several years now. Damage in the form of pinhole leaks, and small cracks that could lead to breaching of fuel cladding is "not explicitly defined in [NRC] Regulations, staff guidance or standards."[28]

High Burnup radioactivity and decay heat

Given these uncertainties the U.S. Department of Energy (DOE) and the NRC have provided general estimates of the radionuclide content of spent nuclear fuel based on current and previous burnup assumptions. According to DOE the estimated average long-lived radioactivity for a typical PWR and BWR assembly having lower burnup at the time of geological disposal are 88,173.69 curies and 30,181.63 curies respectively. [29] For current burnups the NRC estimates that the post discharge radioactive inventory of spent fuel for a typical PWR and BWR assemblies are 270,348.26 curies and 127,056.67 curies respectively (See Figure 2). [30] Approximately 40 percent of the total estimated radioactivity for lower and high burnup is Cs-137.

[26] op cit. Ref 7.
[27] Ibid.
[28] RE Einziger et al., Damage in Spent Nuclear Fuel Defined by Properties and Requirements, U.S. Nuclear Regulatory Commission, Spent Fuel Project Office, June 2006. http://pbadupws.nrc.gov/docs/ML0608/ML060860476.pdf
[29] U.S. Department of Energy, Final Environmental Impact Statement, for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada, 2002, Appendix A, Tables A-7, A-8, A-9, A-10, (PWR/ Burn up = 41,200 MWd/MTHM, enrichment = 3.75 percent, decay time = 23 years. BWR/ Burn up = 36,600 MWd/MTHM, enrichment = 3.03 percent, decay time = 23 years.)
[30] U.S. Nuclear Regulatory Commission, Characteristics for the Representative Commercial Spent Fuel Assembly for Preclosure Normal Operations, May 2007, Table 16, p.44-45. http://pbadupws.nrc.gov/docs/ML0907/ML090770390.pdf

Figure 2 estimated radioactivity in a U.S. spent nuclear fuel assembly



Sources: DOE EIS-0250, Appendix A, http://energy.gov/sites/prod/files/EIS-0250-FEIS-01-2002_0.pdf
NRC http://pbadupws.nrc.gov/docs/ML0907/ML090770390.pdf

This substantial increase in spent nuclear fuel radioactivity has also resulted in a commensurate increase in decay heat. After removal, the spent fuel gives off a significant amount of heat as the radioisotopes decay. After removal, the spent fuel gives off a significant amount of heat as the radioisotopes decay(see Figures 3 and 4). The offload of a full reactor core at a PWR is estimated to give off about 42,000 BTU/hr (12,310 watts). [31] Within one year the heat output of the spent fuel diminishes by about ten times. The decay heat for a five-year cooled PWR assembly with a discharge exposure of 55 GWd/MTU is approximately 1,500 watts. [32] The decay heat for a five-year cooled BWR assembly with a discharge exposure of 48 GWd/MTU is approximately 480 watts. [33]

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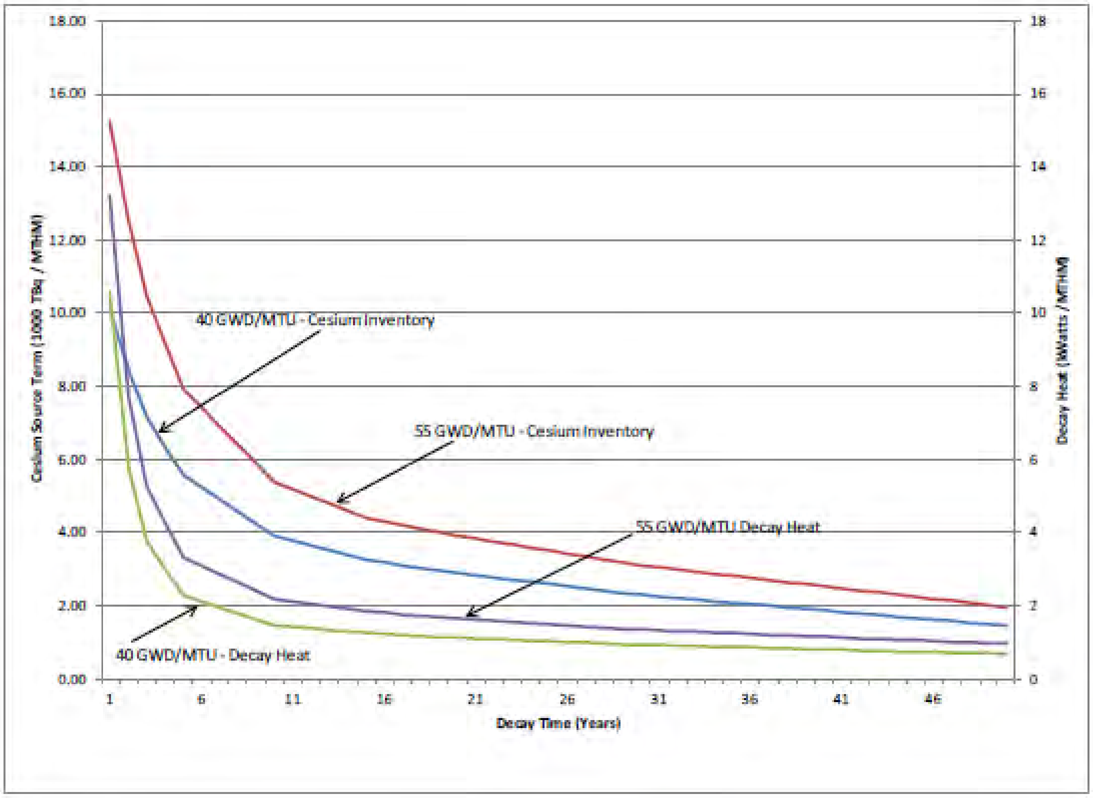
31 U.S. Nuclear Regulatory Commission, Safety Evaluation by the Office of Nuclear Safety Regulation Related to Amendment No. 131 to Facility Operating License No. NPF-10 and Amendment 120 to Facility Operating License No. NPF-15, Docket Nos. 50-361 and 50-362, October 1996, P. 6. http://pbadupws.nrc.gov/docs/ML0220/ML022000232.pdf

32 Op Cit Ref.1.

33 Ibid.

Figure 3 PWR SNF Assembly Decay Heat (right axis) and Cesium Inventory (left axis) as a Function of Burnup and Cooling Time

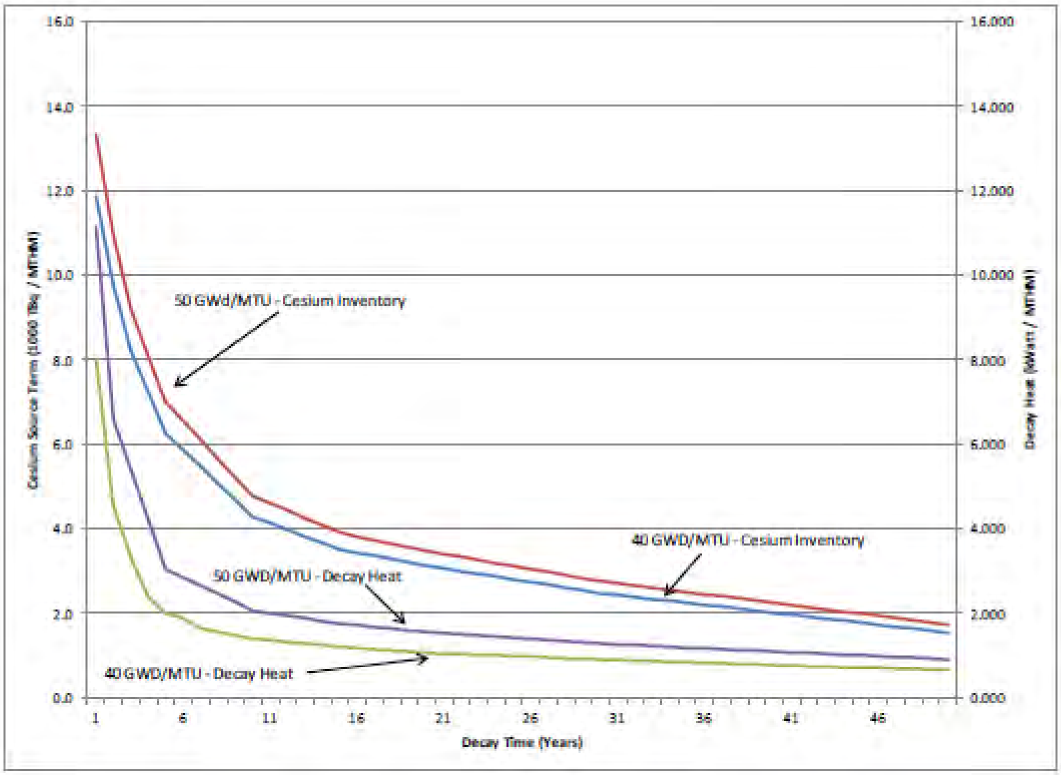


Source: Supko/EPRI 2012

Within one year the heat output of the spent fuel diminishes by about ten times. After 10 years it drops by another factor of ten. By 100 years the decay heat has dropped another five times, but still gives off significant heat.[34] However, the decay heat remains substantially high throughout the operation of the reactors and well after they are closed.

34 Op Cit Ref. 4.

Figure 4 ***BWR SNF Assembly Decay Heat (right axis) and Cesium Inventory (left axis) as a Function of Burnup and Cooling Time [***



(Source: Supko/E{RI 2012)

Control of decay heat is a key safety factor for spent fuel storage and its final disposal in a geological repository. Storage of spent nuclear fuel in pools requires continuous cooling for an indefinite period to prevent decay heat from igniting the zirconium cladding and releasing large amounts of radioactivity into the environment.

Zirconium cladding of spent fuel is chemically very reactive in the presence of uncontrolled decay heat. According to the National Research Council of the National Academy of Sciences the build up of decay heat in spent fuel in the presence of air and steam:

> " is strongly exothermic – that is, the reaction releases large quantities of heat, which can further raise cladding temperatures… if a supply of oxygen and or steam is available to sustain the reactions.. The result could be a runaway oxidation – referred to as *a zirconium cladding fire* – that proceeds as a burn front (e.g., as seen in a forest fire or fireworks sparkler)...As fuel rod temperatures increase, the gas pressure inside the fuel rod increases and eventually can cause the cladding to balloon out and rupture.[original emphasis] "[35]

35 National Research Council, Board on Radioactive Waste Management, Committee on the Safety and Security of Commercial Spent Nuclear Fuel Storage, National Academes Press (2006), p. 38-39.

The Nuclear Regulatory Commission (NRC) has performed several studies to better understand this problem. In 2001, the NRC concluded:

> "… it was not feasible, without numerous constraints, to establish a generic decay heat level (and therefore a decay time) beyond which a zirconium fire is physically impossible."[36]

In terms of geologic disposal, decay heat, over thousands of years, can cause waste containers to corrode, negatively impact the geological stability of the disposal site and enhance the migration of the wastes.[37]

EPRI points out that radiocesium inventories have greatly increased as well as decay heat. It contends that a return to open-rack cooling of SNF would result in a reduction in the potential source term of 43% to 53% for a PWR and 47% to 48% for a BWR.

High burnup and Deterioration of Spent Fuel Pool Equipment

The accumulation of high-burnup spent nuclear fuel in pools adds to the growing concern over age and deterioration of spent fuel pool storage systems. A 2011 NRC-sponsored study, concluded," *as nuclear plants age, degradations of spent fuel pools (SFPs), reactor refueling cavities…are occurring at an increasing rate, primarily due to environment-related factors. During the last decade, a number of NPPs have experienced water leakage from the SFPs [spent fuel pools] and reactor refueling cavities.*[38] The authors of this study also indicate that accurate assessment of aging of spent fuel pools is uncertain because, *"it is often hard to assess their in situ condition because of accessibility problems…. Similarly, a portion of the listed concrete structures are either buried or form part of other structures or buildings, or their external surfaces are invisible because they are covered with liners.* [39] .

High-density racks in spent fuel pools at U.S. power plants pose potential criticality safety concerns associated with the deterioration of neutron absorbing panels that allow spent fuel rods to be more closely packed. Since 1983, several incidents have occurred at reactors around the U.S. with these panels in which the neutron-absorbing materials deteriorated, and in some cases, bulged, causing spent fuel assemblies, containing dozens of rods each, to become stuck in submerged storage racks in the pools. This problem could lead to structural failures in the storage racks holding the spent fuel rods in place.

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http://www.nap.edu/openbook.php?record_id=11263&page=38
,http://www.nap.edu/openbook.php?record_id=11263&page=39

36 U.S. Nuclear regulatory Commission, Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants, October 2000, P. ix. http://pbadupws.nrc.gov/docs/ML0104/ML010430066.pdf

37 R. Wigeland, T.Taiwo, M. Todosow, W. Halsey, J. Gehin, Options Study – Phase II ,Department of Energy, Idaho National Laboratory, INL/EXT-10-20439, September 2010. http://www.inl.gov/technicalpublications/Documents/4781584.pdf

38 U.S. Nuclear regulatory Commission, A summary of Aging Effects and Their Management in Reactor Spent Fuel Pools, Refuelling Cavities, TORI and Safety-Related Concrete Structures, NUREG/CR-7111 (2011). P. vxiii. http://pbadupws.nrc.gov/docs/ML1204/ML12047A184.pdf

39 Ibid.

According to the NRC in May 2010:

> The conservatism/margins in spent fuel pool (SFP) criticality analyses have been decreasing…The new rack designs rely heavily on permanently installed neutron absorbers to maintain criticality requirements. *Unfortunately, virtually every permanently installed neutron absorber, for which a history can be established, has exhibited some degradation. Some have lost a significant portion of their neutron absorbing capability. In some cases, the degradation is so extensive that the permanently installed neutron absorber can no longer be credited in the criticality analysis* [emphasis added].[40]

For example, in 2007, South California Edison (SCE) reported to the NRC that Boraflex neutron absorbing panels have deteriorated to the point at the San Onofre Nuclear Generating Station Units 2 and 3 spent nuclear fuel pools where it was doubtful they could be credited to prevent criticality. SCE proposed installing borated stainless steel tube guide inserts, and to add more neutron absorbing boron to the pool water.[41] According to SCE deterioration from erosion, over a period of 15 months, increased the level of particles from disintegrated neutron absorbing panels in the pool water by 134 percent.[42] These particles place an additional strain on pool water cleaning systems.

NRC's response to this problem has been to allow operators to add additional boron to the pool water to compensate for the loss of re-criticality protection from deteriorated neutron absorbing panels. However, boron is implicated in possible deterioration of the reinforced concrete holding the spent fuel pools. Concrete "could be negatively impacted by adverse environments of borated water or where there is the possibility of alkali aggregate material reactivity."[43]

Equipment installed to make high-density pools safe exacerbates the danger of spent fuel cladding ignition, particularly with high burnup spent fuel. In high-density pools at pressurized water reactors, fuel assemblies are packed about nine to 10.5 inches apart, just slightly wider than the spacing inside a reactor. To compensate for the increased risks of a large-scale accident, such as a runaway nuclear chain reaction, pools have been retrofitted with enhanced water chemistry controls and neutron-absorbing panels between assemblies.

The extra equipment restricts water and air circulation, making the pools more vulnerable to systemic failures. The ability to remove decay heat from spent fuel pools to prevent boiling corresponds to the amount of water displaced in the pool by spent fuel and the equipment that allows for its tight packing. High density storage also impacts the ability of water to flow through the pool. If the equipment collapses or fails, as might occur during a destructive

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40 U.S. NRC, Office of Nuclear Reactor Regulation, On Site Spent Fuel Criticality Analyses, NRR Action Plan, May 21, 2010. http://pbadupws.nrc.gov/docs/ML1015/ML101520463.pdf

41 South California Edison, Letter to the NU.S. Nuclear regulatory Commission, Subject: Docket Nos. 50-361 and 50-362 Amendment Application Numbers 243, Supplement 1 and 227, Supplement 1 Proposed Change Number (PCN)566, Revision 1, Request to Revise Fuel Storage Pool Boron Concentration, San Onofre Nuclear Generating Station Units 2 and 3, June 15, 2007, Enclosure 2,p. 2. http://pbadupws.nrc.gov/docs/ML0717/ML071700097.pdf

42 Ibid.

43 Op. Cit Ref. 38, p.xiv.

earthquake or terrorist attack, air and water flow to exposed fuel assemblies would be obstructed, causing a fire, according to the NRC's report. Heat would turn the remaining water into steam, which would interact with the zirconium, making the problem worse by yielding inflammable and explosive hydrogen.