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Written Closing Remarks from Xylene Power Ltd.

Observations écrites finales de Xylene Power Ltd.

In the Matter of

À l'égard de

Ontario Power Generation Inc.

Ontario Power Generation Inc.

OPG's Deep Geological Repository (DGR) Project for Low and Intermediate Level Radioactive Waste

Installation de stockage de déchets radioactifs à faible et moyenne activité dans des couches géologiques profondes

Joint Review Panel

Commission d'examen conjoint

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DEEP GEOLOGIC REPOSITORY - CLOSING REMARKS

By Charles Rhodes, P. Eng., Ph.D. , Xylene Power Ltd., September 22, 2014

EXECUTIVE SUMMARY:

A Deep Geologic Repository (DGR) is required for short, medium and long term storage of many thousands of tons of Canadian nuclear wastes. However, the Bruce DGR, as proposed by Ontario Power Generation (OPG), lacks the capacity, long term accessibility, safety, security and cost control features that the Ontario nuclear power industry will require over the next 60 years.

Completely missing from the OPG DGR plan is any understanding of the basic physics that sets the amount of non-fossil electricity generation that Ontario must build over the coming 60 years and any understanding of the power system parameters that will set the fraction of that new non-fossil electricity generation capacity that must be nuclear. Of particular concern in this respect is the amount of electrical energy that will be required to produce synthetic hydrocarbons to replace fossil fuels.

The primary purpose of the DGR should be to physically protect stored containers of radio isotopes. Secondary purposes of the DGR are to warn of an approaching radio isotope container failure, to enable safe radio isotope access for material recycling, to enable facility and container inspection and maintenance and to provide backup radio isotope isolation in the event of a container breach. The DGR location should be chosen so that it remains naturally dry via a combination of high density granite rock, high elevation, gravity drainage and natural ventilation.

The proposed Bruce DGR lacks multiple essential features and hence should be abandoned in favor of an alternate DGR that is remote, high, dry, long term accessible and formed in high density nearly crack free granite. Subject to appropriate changes in legislation and regulation such an alternate DGR could also be used for storage and recycling of spent nuclear reactor fuel, at a major cost saving to Ontario electricity ratepayers and Canadian taxpayers.

To protect the alternate DGR from repeated future glaciations the alternate DGR storage vaults should be formed about 400 m below grade. To provide safe long term accessibility for material recycling, safety inspection and facility maintenance the alternate DGR vaults should be formed in stable high density granite at an elevation at least 300 m above the local water table. To ensure toxic radio isotope isolation the radio isotopes should be stored in engineered containers and the surrounding granite should be nearly crack free. To ensure dry storage conditions and to provide ongoing certainty about overall DGR performance the DGR should be gravity drained to a sump which is instrumented for detection of liquid borne radio isotopes. This sump must have sufficient storage capacity for trapping liquid borne radio isotopes until remedial measures can be implemented.

Allowing for the DGR vault height and for local topographical variations the DGR should be formed inside a mountain with a dense water tight granite core that rises at least 800 m above the local water table. The presence of 200 m of limestone overburden will minimize granite cracking. Such geography exists in British Columbia and Labrador but is almost non-existent in Ontario.

This geological configuration allows ongoing DGR operation with minimal water pumping and with natural ventilation. These two features vastly reduce the DGR facility's ongoing operating cost.

For protection against a malevolent attack the DGR should have an immediately surrounding ~ 4000 hectare security zone bounded by natural barriers such as high mountain cliffs and deep gorges. Outside the security zone there should be an ~ 16,000 hectare exclusion zone in which only DGR related activities are permitted. The combined security zone and the exclusion zone is an approximately circular area with a radius of 8 km (5 miles). At an ideal DGR location there should also be a government enforced restriction on new development (such as by declaration of a national or provincial park) within a 40 km (25 mile) radius of the DGR so that the impact on the

public of any future DGR accident and/or malevolent attack would be minimal. Note that the contemplated 40 km radius is twice the exclusion radius adopted by Japan around the failed Fukushima Daiichi nuclear power plants.

Due to uncertainty with respect to the long term radio isotope containment capability of natural rock, especially after unforeseeable future earthquake events, the primary means of radio isotope containment should be engineered double wall corrosion resistant containers that, subject to damping by pea gravel, are able to move within the DGR to relieve material stress. Suitable containers can be made with a thick porcelain outer wall, a steel inner wall and with oil between the inner and outer walls. Container seals can be realized with soft metals and/or fluorocarbon grease and/or the natural resin precursor of amber.

Each radio isotope container should have an inductively coupled passive oil level monitoring system that triggers an alarm if there is a failure of either the container's inner wall or outer wall, or if the container is not vertical, or if the container's porcelain top is removed or if the container temperature goes out of its intended operating range. Each container should rest on a flat rock surface that at floor level is surrounded by a silica sand bed. This arrangement provides 4 redundant radio isotope containment barriers (inner steel container, outer porcelain container, silica sand bed and granite rock). The containers are surrounded by pea gravel to give the containers physical protection from earthquakes and overhead rock falls.

The concept of nuclear waste burial out of sight and out of mind below the water table, as is presently advocated by the Nuclear Waste Management Organization (NWMO) and by Ontario Power Generation (OPG), is unreliable due to a combination of water seepage, hydraulic pressure and ion diffusion that makes long term radio active ion containment by natural rock uncertain. Competent parties at the Royal Tyrell Museum in Alberta, who have extensive experience with natural preservation of dinosaur remains, have expressed extreme doubts about long term retention of radioisotopes in limestone. In the presence of water limestone has instabilities that are difficult to reliably predict.

If the OPG proposed radio isotope retention methodology for the proposed Bruce DGR fails there is no practical way to fix the problem. The radioisotope containment concept totally relies on the assumption that natural limestone will provide the required long term containment, in spite of energy instabilities within the limestone that have been reported by NWMO/OPG. This limestone containment concept may work for the isotopes Ca-41 and Cl-36 but is unsuitable for other radio isotopes that should be recycled.

Instead the long term safety concept should be to redesign the OPG nuclear reactor fleet to avoid formation of long lived low atomic weight radio isotopes and to use fast neutrons to transmute long lived high atomic weight radio isotopes into shorter lived radio isotopes that naturally decay to negligible radio toxicity while trapped inside engineered containers that are continuously remotely monitored and can be physically inspected or gamma ray spectra scanned at any time.

The advantage of granite as compared to limestone is much better long term water resistance and structural stability. Once an open DGR is in use it is critical that the probability of an unplanned rock fall that could rupture a container of nuclear waste be extremely small. This probability can be minimized by surrounding the nuclear waste containers with pea gravel that can safely absorb the impact of a minor overhead rock fall and that can safely absorb the lateral motion of an earthquake. Pea gravel can be readily removed to obtain access to the nuclear waste storage containers.

The DGR operation must tolerate an occasional container failure. In a facility holding as many as 10,000 containers for thousands of years it is foolish to assume that there will never be container damage due to an act of God, accident or malevolent event. The containers should have double walls and should be individually remotely monitored. The storage facility should be divided into vaults that, subject to ventilation constraints, are physically isolated from each other. The ventilation air flow should be natural and unidirectional.

The process of nuclear waste transmutation increases the useful energy capture from natural uranium by about 100 fold as compared to the useful energy capture by a CANDU nuclear reactor. However, practical implementation of transmutation involves radioactive material recycling. Hence **there are ongoing DGR access requirements that go far beyond the access provisions embodied in the proposed Bruce DGR**.

In addition, low and intermediate level nuclear waste recycling can recover hundreds of millions of dollars worth of zirconium, nickel, and tritium/helium-3 from the reactor refurbishment and decommissioning waste. This waste recycling will substantially reduce the future required DGR volume and the future total radio isotope inventory, thus making the entire nuclear energy and nuclear waste disposal cycle safer and more economic.

The cost of forming a high, dry and accessible DGR in a suitable existing depleted mine within a granite core mountain is much less than the cost of forming a comparable capacity new low, wet and inaccessible DGR in limestone. Further, the ongoing costs of pumping and mechanical ventilation associated with a low and wet DGR in limestone are almost completely avoided by use of a high, dry and accessible DGR in granite.

Really low level nuclear waste with no recycling value, such as uranium ore tailing and mildly irradiated concrete rubble, should not go in a DGR. Instead such waste should be used to back fill existing depleted uranium mines.

The money saved by adoption of a high, dry and accessible DGR in granite should be used to develop a liquid sodium cooled fast neutron reactor technology in Ontario for displacement of fossil fuels and for recycling/disposal of spent reactor fuel.

Liquid sodium cooled fast neutron reactors are required to enable full displacement of fossil fuels by U-238 and hence to prevent a near term global extinction due to atmospheric CO_2 triggered thermal runaway.

Lists of practical recommendations are offered to the DGR Joint Review Panel (JRP).

ISSUES FORCING CONSTRUCTION OF AN ACCESSIBLE DGR:

1. Due to the high non-equilibrium CO_2 concentration in the Earth's atmosphere caused by combustion of fossil fuels the Earth is absorbing more solar energy than it emits via infrared radiation. As a result of this net heat absorption the Earth's climate is gradually changing. Due to the existence of two locally stable atmospheric thermal states, as indicated by PETM mass spectrometry data and by Earth thermal emission data, at an atmospheric CO_2 concentration of about 722 ppmv the Earth will enter a condition of thermal runaway in which the atmospheric CO_2 concentration spontaneously increases. In these circumstances and the Earth will become very hot even if combustion of fossil fuels ceases. The only hope of stabilizing the Earth's climate at normal temperatures is via total abandonment of fossil fuels. Such fossil fuel abandonment requires wide spread use of nuclear power for synthesis of replacement liquid hydrocarbons.

2. The only source of nuclear energy sufficient to sustainably displace fossil fuels is U-238.

3. Realizing the contemplated energy from U-238 requires liquid sodium cooled Fast Neutron Reactors (FNRs).

4. The advantages of liquid sodium cooled FNRs are that they can reduce the net generation of nuclear waste by about 100 fold as compared to CANDU reactors and FNRs can reduce the radio toxicity lifetime of existing spent CANDU reactor fuel by about 1000 fold.

5. A further advantage of adoption of liquid sodium cooled FNRs is that the FNR cores and fuel can be fabricated from radioactive waste resulting from refurbishment and decommissioning of CANDU reactors.

6. Canada has a growing inventory of medium and high level nuclear waste, currently more than 100,000 tons.

7. Due to future requirements for nuclear energy to provide base load electricity without emission of CO_2, nuclear waste will continue to be generated far into the future. If CANDU technology is

retained, in the future nuclear waste will be generated at least 7 X faster than at present.

8. Some high atomic weight radio active isotopes are highly toxic and must either be transmuted into short lived isotopes or must be kept isolated from ground water for as long as 1,000,000 years into the future. AECL recognized this problem prior to 1966 but the Canadian government of the time refused to fund the contemplated transmutation facility, then known as an Intense Neutron Generator (ING).

9. Today safe disposal of nuclear waste is an issue that our society must face.

THE NWMO / OPG DGR CONCEPT AND ITS PROBLEMS:

1. The nuclear waste disposal concept presently advocated by the NWMO and OPG is burial of unprocessed nuclear waste in a 680 m deep hole in limestone close to Lake Huron. Such a DGR can reasonably be characterized as low, wet and future inaccessible.

2. The NWMO / OPG safety case rests on the assumption that most nuclear waste radio isotopes will naturally decay before they diffuse into near surface ground water. Some nuclear waste isotopes, such as Ni-59, Ca-41 and Cl-36 have very long half lives and will remain significantly toxic for about one million years into the future. Thus the NWMO/OPG safety case is dependent upon either dilution or upon the validity of a series of assumptions relating to long term subsurface behavior. There is no backup radio isotope containment mechanism.

3. Reduction of pollution by dilution might be acceptable if Canada was never to build another nuclear reactor, but is not sustainable in a future that involves much more nuclear power in Ontario than at present.

4. The NWMO / OPG safety case involves unproven claims regarding the existence of a sedimentary rock region in which the hydraulic pressure decreases with increasing depth. Such a region, if it truly exists, is from an energy perspective inherently unstable. This author, who has hands on experience with relevant deep well instrumentation, suspects that there may be systematic errors in the OPG piezometer data at depths below 450 m. This author wrote to OPG about this problem and how to diagnose it but did not receive a satisfactory reply.

5. The OPG safety case involves a mathematical model based on the Darcy formula which in turn relies on an assumption of laminar water flow. This laminar water flow assumption is simply not true for tight rock under a high hydraulic pressure gradient, as is the case near an open DGR. Experimental observations show that in circumstances where rock is under a high hydraulic pressure gradient most of the water flow is turbulent along capillary channels, not laminar flow as implicitly assumed by NWMO / OPG. Thus the OPG hydraulic flow model is wrong. The significance of this error relates to a known subsurface water body not far below the planned depth of the Bruce DGR.

6. **OPG has failed to consider the ongoing cost of the pumping and ventilation necessary to keep the proposed Bruce DGR dry and has failed to measure the actual subsurface seepage rate at the proposed Bruce DGR location.** This subsurface seepage rate will be a function of vertical water flow behind the access shaft liners. There may be huge costs related to minimization and long term extraction of this vertical water flow. Compression grouting around the proposed DGR access shafts may be more difficult and more expensive than compression grouting at the Bennett Dam on the Peace River.

7. The total ground water problem at the proposed Bruce DGR is a combination of seepage, static pressure and ion diffusion issues, none of which have been properly quantified by NWMO / OPG. The present DGR plans rest on theoretical models. As a minimum there needs to be actual seepage flow measurements at the proposed Bruce DGR shaft locations before there is any further financial commitment to this DGR location.

8. The ground water penetration problem has been multiplied by personnel issues at NWMO / OPG. These persons have repeatedly rejected good advice from the Canadian hard rock mining industry. The NWMO has visited various foreign DGR project sites but, in spite of multiple written

invitations, has failed to inspect an existing large, high, dry and accessible Canadian DGR. Due to absence of interest by NWMO/OPG in late 2013 this superior Canadian DGR was purchased by Margaux Resources, an entity controlled by China.

9. At the time of drafting of this document senior persons in the Canadian mining industry do not believe the OPG claim that at a depth of 680 m below Lake Huron the water seepage into an unlined DGR is and will remain negligible. Water will tend to flow downwards vertically behind the access shaft liners and down any vertical rock cracks or fractures. Mine and dam experience indicates that this vertical water flow will get larger over time as fine grout particles are gradually washed out. The costs of ongoing water exclusion and removal may make the idea of keeping the proposed Bruce DGR open for 60 years financially unsustainable.

10. Due to the local pressure decrease triggered by construction of the DGR water of hydration will seep out of the DGR walls into the DGR, increasing the load on the DGR pumping and ventilation systems. Any sort of sustained labor problems, power supply problems or equipment maintenance problems could easily lead to flooding of the open unlined DGR. Simply put, the proposed Bruce DGR while open will be a major accident waiting to happen.

11. The proposed Bruce DGR could flood due to an act of God such as: a prolonged power failure, an earthquake that causes a vertical rock crack through the DGR, an earthquake that breaks the access shaft vertical water seals, an extreme rain storm or a tsunami on Lake Huron.

P>12. There is no practical plan for dealing with the radioactive water that will result if the proposed Bruce DGR floods. The problems with radio isotope contaminated DGR flood water would be comparable to the problems presently faced in Japan with contamination of ground water by the damaged Fukushima Daiichi nuclear reactors.

13. The Japanese cleanup of contaminated ground water at Fukushima Daiichi will cost many billions of dollars. This problem, which is rooted in utility overconfidence/negligence, should never be faced by the electricity ratepayers of Ontario. Potential ground water problems can easily be avoided by relocation of the DGR to a naturally dry location that is high above the local water table. The incompetent OPG/NWMO executives that are responsible for the choice of the proposed Bruce DGR site should be terminated forthwith.

14. The failure of NWMO / OPG to measure the actual seepage rate in a test well at the proposed Bruce DGR location and the failure of NWMO / OPG to at least inspect the alternative high, dry, water tight and accessible Jersey Emerald DGR in British Columbia indicates that the entire Bruce DGR project is a scam.

DGR AND NUCLEAR WASTE PROCESSING ALTERNATIVES:

1. The NWMO has failed to pursue known techniques for transmuting long lived high atomic weight radio isotopes into much shorter lived radio isotopes, which are much more manageable from a long term safety perspective. These techniques have been known since the early 1960s when they were extensively studied by Atomic Energy of Canada Limited (AECL). After federal government cancellation of the AECL Intense Neutron Generator (ING) Project in the mid 1960s these techniques disappeared from the Canadian university engineering curriculum. This author knows about this matter because he received ING Project data in early 1969 and because he taught engineering at the University of Toronto for six years (1969-1975) and is further familiar with the scope of the current CANDU curriculum at Ontario University Institute of Technology (OUIT).

2. The modern implementation of spent reactor fuel transmutation for toxicity reduction is known as the Ottensmeyer Plan. Professor Peter Ottensmeyer was treated with great disrespect by uninformed representatives of NWMO / OPG when he appeared before the DGR Review Panel. For example Frank King of the NWMO referred to an imaginary requirement for forming radio active zirconium into sheets, which is simply not true and which demonstrates Frank King's lack of relevant knowledge. (DGR Review Panel Transcript October 9, 2013 Vol. 20 Page 133 Line 2 to Page 134 Line 24). In the Ottensmeyer Plan radio active zirconium is not made into tubes. It is

instead directly alloyed with the metallic component of spent CANDU fuel that remains after selective chemical extraction of about 90% of the uranium.

3. OPG has chosen an uneconomic low, wet and inaccessible DGR location for no credible reason. There are far more suitable potential DGR locations elsewhere in Canada in places such as British Columbia and Labrador. Even the higher elevation portions of the Canadian shield could be used, although the elevation related safety margins in the Canadian Shield are less than optimal and the granite cracking is more than optimal.

4. From safety, economic and material recycling perspectives a high, dry and accessible DGR is much more viable than a low, wet and inaccessible DGR.

5. Clear benefits of a high, dry and accessible DGR are that: it allows recycling of radio active materials, it limits the growth of the nuclear waste inventory, it reduces the future cost of nuclear power generation, it allows ongoing: safety monitoring, inspection and maintenance and it provides future generations certainty with respect to the safe storage of toxic radioisotopes. Benefits of near term importance are recycling of zirconium, nickel, tritium / helium-3 and spent CANDU fuel.

6. Zirconium is a valuable metal that is widely used in nuclear reactors because of its low neutron absorption cross section. Neutron irradiated zirconium is radio active but it is easily alloyed with the metallic components of spent CANDU fuel to form metallic Fast Neutron Reactor (FNR) fuel. FNR fuel conserves scarce resources by improving natural uranium utilization efficiency over 100 fold as compared to a CANDU reactor. The process for alloying zirconium with spent CANDU fuel to make FNR fuel has been field proven in the EBR-2 and is far simpler than the method described to the DGR Review Panel by Frank King of the NWMO (Hearing Transcript October 9, 2013 Vol. 20 page 133 Line 2 to Page 134 Line 24.)

7. Nickel is a major component of Inconel 600 and stainless steel, both of which are widely used in nuclear power plants. The price of non-radio active nickel in recent years has been between $6 per lb and $13 per lb. Nickel forms 10% to 15% of stainless steel and about 72% of Inconel 600. Each nuclear power plant involves hundreds of tons of nickel, so nickel recycling is a major issue.

8. The CANDU nuclear reactor steam generators are not directly neutron irradiated. Hence the nickel contained in the steam generators can be recovered by a chemical-mechanical process that first strips the radio active scale from the interior of the Inconel 600 heat exchange tubes. This recovered nickel can be used in non-nuclear applications.

9. The nickel contained in neutron irradiated metal alloys can be chemically purified using conventional electrochemical processes. This radioactive nickel can be reused for fabrication of FNR fuel tubes.

10. Tritium is required as a future nuclear fusion fuel. Tritium decays with a half life of 12.6 years into helium-3. Helium-3 is essential for certain medical and nuclear security applications (neutron detection) and for a nuclear heat production process known as Micro Fusion. During the last decade the price of helium-3 has varied from $1000 / gm to $10,000 / gm. Hence burial of nuclear waste containing tritium makes no economic sense. The exhaust gas from nuclear waste containing tritium should be captured in sealed containers and the stable helium-3 should be vacuum extracted and concentrated using cryogenic techniques.

11. For all of the above mentioned reasons much of the so called “Low and Medium Level Nuclear Waste” is not waste at all and should be treated as material in short term storage pending recycling. For this reason these waste components should be stored in air tight corrosion resistant containers and the DGR should be high, dry and long term accessible.

12. This author advised the NWMO about an existing alternative high, dry and accessible Canadian DGR at Jersey Emerald in October 2010. This Canadian 500,000 m^2 DGR was formed in WWII and is water tight. In 2013 this alternative DGR together with 4000 hectares of surrounding properties (security zone) was offered to the NWMO / OPG at a price of $67.5 million. This alternative DGR is larger, safer, naturally dry, much more remote and much more secure than the

OPG proposed Bruce DGR. In 2013 the NWMO and OPG both failed to send representatives to the Jersey Emerald site inspection and neither organization posted the $2 million deposit required to prevent sale of the Jersey Emerald DGR to a Chinese controlled entity, Margaux Resources Ltd.

NWMO / OPG FALSE CLAIMS:

1. Mark Jensen of the NWMO claimed to the Joint Review Panel (JRP) that the subsurface at Jersey Emerald has not been adequately studied. That claim is completely false. There is vastly more reliable subsurface data available with respect to Jersey Emerald and its surroundings than exists with respect to the proposed Bruce DGR. Jersey Emerald has been intensely studied for over 70 years by multiple major mining companies. During World War II and the Korean War Jersey Emerald was key to the allied nations production of zinc for galvanizing steel, lead for bullets and tungsten for armor penetrating munitions. About 6000 documented drill cores have been extracted from Jersey Emerald and the immediately surrounding area. From this drill core data and from underground surveys a three dimensional subsurface computer model of Jersey Emerald has been constructed. This model shows an ~ 800 m high granite uplift under ~ 200 m of limestone overburden. This granite uplift is water tight as indicated by a multi-year high pressure water test.

2. OPG has claimed that the projected cost of the proposed Bruce DGR is about $700 million. The actual cost of the Niagara Tunnel, which was a recent project of comparable scope in similar rock, but less than 1 / 4 as deep, was $1.5 billion. This author reasonably anticipates that to limit long term seepage the Bruce DGR will require a rigid watertight liner, similar to the Niagara Tunnel but much thicker. Hence, based on actual costs incurred in other lined tunnel projects, the cost of the Bruce DGR, if it proceeds, will likely be in the range $2.5 billion to $5 billion. The costs of keeping the Bruce DGR open over 60+ years will be every bit as great as the costs of keeping open a similar sized mine or tunnel in similar rock at a similar depth with a similar overhead body of water. Unrealistic claims by OPG relating to these ongoing costs should be rejected.

3. OPG has claimed that the costs of shipping nuclear waste by rail to the Jersey Emerald DGR are prohibitive. This OPG claim is entirely without merit. Large volumes of much more hazardous materials such as oil, liquid chlorine and liquid ammonia are routinely and frequently shipped by rail across Canada along the same route.

4. Recent news reports indicate that annual oil shipments by rail in Canada are:
140,000 rail car loads / year X 90 tons / carload = 12,600,000 tons / year.
Thus annual Canadian oil shipments by rail are more than 250 times the total Canadian high level nuclear waste inventory.

5. Based on the above mentioned financial numbers this author is forced to the conclusion that there is deep seated incompetence and/or corruption at both the NWMO and OPG.

6. OPG has minimized the danger related to a malevolent attack on a container of metallic zirconium. The blowtorch tests offered by OPG do not portray the hazard that exists when zirconium is vaporized by a suitably shaped fast explosive charge similar to the warhead of an anti-tank or anti-ship missile. The consequences of a malevolent attack on a container of radio active and chemically active metal such as zirconium or uranium should not be underestimated. This author has had first hand tragic experience with a comparable multimillion dollar explosion and aluminum fire in a large subterranean electrical vault.

7. If the JRP does not believe that metals such as aluminum and zirconium burn violently the panel should refer to the case of the British destroyer, HMS Sheffield, with an aluminum superstructure that burned violently with large casualties and loss of life when hit by an Exocet missile during the Falklands war. Today aluminum is no longer used for superstructure weight reduction on warships because it can be ignited by a suitably shaped fast explosive charge. Zirconium has similar combustion properties to aluminum. It must be vaporized in an air atmosphere to ignite, but once ignited zirconium burns intensely. Attempts to extinguish a zirconium fire with water will cause formation of hydrogen which can multiply problems.

8. The best solution to the problem of a malevolent attack on a container of radioactive material is to do all necessary to prevent such an attack. The simplest way to remove motivation for a sophisticated malevolent attack is to locate the DGR at a place that is far from any population center. To minimize the risk containers of radioactive metallic zirconium, metallic uranium and metallic trans-uranium actinides should be back filled with argon instead of air. Further, these containers should have sufficient structural strength to resist rupture when attacked by a small shaped explosive charge such as an RPG warhead. If the attacking charge is sufficiently large to cause a full container rupture instead of a small hole, there is likely no practical way to limit the resulting fire other than by suffocation. In this respect a DGR vault or a railway box car containing a radioactive and chemically active metal such as zirconium should be fitted with a nitrogen/argon fire suppression system.

CHOICES AVAILABLE TO THE JOINT REVIEW PANEL:

1. The Joint Review Panel (JRP) can recommend senior management changes at OPG but may be without power to implement such changes.

2. The NWMO is controlled by the federal Minister of Natural Resources. Hence the JRP can recommend to the Minister of Natural Resources that the entire senior management of the NWMO be terminated and replaced by persons who are prepared to act in the national interest rather than follow their own narrow personal agendas. **The national interest involves getting value for the tax payer dollar and enabling nuclear energy for displacing fossil fuels** while ensuring prevention of long term environmental pollution. The national interest is not served by making unrealistic promises to aboriginal organizations or by spending tens of billions of taxpayer/ratepayer dollars on low, wet and inaccessible DGRs when better high, dry and accessible DGR locations are readily available for only a few tens of millions of dollars.

3. The JRP can decide that neither the safety case, nor the long term environmental protection case nor the economics case for the Bruce DGR has been demonstrated. Hence the Bruce DGR has failed its environmental assessment application.

4. The JRP can recommend that OPG purchase a potential DGR site in high density granite that is at least 300 m above the local water table, that has at least 400 m of overhead rock to protect against repeated glaciations, that can be made naturally dry via gravity drainage and that is long term accessible. Due to the elevation requirements such a DGR location is unlikely to be found in Ontario. Locations in the Selkirk Mountains of southern British Columbia, in the watershed of the Columbia River, are particularly suitable because of physical security and because of zero impact on migratory fish. There are other less ideal potential DGR locations in BC, Alberta, Yukon, Quebec and Labrador. If the elevation related safety margins are reduced the highest elevation portions of the Canadian Shield in Ontario could be considered.

5. The JRP can recommend that OPG purchase the Jersey Emerald DGR. The Jersey Emerald DGR complies with the aforementioned elevation specifications, provides natural physical security, and is in the water shed of the Columbia River which, due to downstream US hydroelectric dams, has no migratory fish. Further, the presence of the downstream US Richland Nuclear Reservation minimizes the international consequences of a DGR at Jersey Emerald.

6. The JRP can recommend that the federal Minister of Natural Resources inform the present owners of the Jersey Emerald related properties **that the Jersey Emerald surface and mineral rights are an essential Canadian asset which if necessary will be acquired by government expropriation** if the present owners fail to transfer the property title and mineral rights to the NWMO or OPG. The title and rights transfer agreement should include reasonable provisions to allow continuing extraction of remaining mineral ore deposits from the Jersey Emerald area.

7. **In the event that the JRP finds itself politically forced to approve the Bruce DGR the JRP members can protect their own reputations by demanding that any such approval be entirely contingent on formation of test wells at the proposed Bruce DGR access shaft locations and measurement of an acceptable water seepage rate into these test**

wells. If the average seepage rate into the unlined Bruce DGR test wells exceeds 1 mm / hour then the Bruce DGR will be economically non-viable from a pumping and ventilation cost perspective.

8. **The JRP can recommend that low and medium level nuclear waste containing significant amounts of zirconium, nickel, copper, tritium / helium-3 and plutonium-239 / uranium-238 must not be placed in the Bruce DGR due to the inherent high future recycling value of these materials.** When these materials are excluded from the proposed Bruce DGR the economic case for the proposed Bruce DGR may collapse.

9. The JRP can recommend that the contents of the Western Waste Management Facility be moved as soon as practical to a much higher elevation storage location where there is much less risk of flooding due to extraordinary acts of God.

10. The JRP can recommend that **money presently being set aside for disposal of high level nuclear waste be redirected to development of a liquid sodium cooled fast neutron power reactor in Ontario together with a single large high, dry and accessible DGR in granite to be located in another province for storage of all of Canada's intermediate and high level nuclear waste.** By following this path many billions of taxpayer and electricity ratepayer dollars can be saved.

11. The JRP can recommend that the NWMO as it presently constituted be fundamentally changed or wound up. The present NWMO personnel lack the essential mining related knowledge and skills that are required for implementation of a high, dry and accessible DGR in granite and further lack the essential nuclear and radio chemical related knowledge that is required for implementation of a fast neutron reactor fuel cycle.

12. **Canada has plenty of capable young people who yearn to make the world a better place through implementation of a liquid sodium cooled fast neutron nuclear reactor technology that efficiently utilizes spent CANDU fuel and other CANDU waste materials such as zirconium, nickel and tritium/helium-3.** The single most important task for the DGR Review Panel is to enable the efforts of these young people. Spending billions of dollars of scarce public money on burial of unprocessed nuclear waste in a low, wet and inaccessible DGR with uncertain long term containment is not a solution to the nuclear waste problem and denies our youth access to important recyclable materials that they will need to build nuclear reactors that can displace fossil fuels.

SUMMARY:

1. I have set out herein appropriate methodologies for dealing with the dominant radio nuclei that arise out of the operation of CANDU nuclear reactors and FNRs.

2. The current OPG/NWMO plan for the Bruce DGR does not adequately address material recycling. Of particular concern is inattention to recycling of nickel, zirconium, helium-3 and neutron reflector carbon. During the Joint Review Panel hearing in the autumn of 2013, the expert offered by the NWMO had no knowledge of the critical role of zirconium in fast neutron reactor fuel and had no knowledge of the related fuel processing nuclear chemistry. There is an unacceptable level of technical incompetence within the senior managements of both the NWMO and OPG.

3. A major problem with the proposed Bruce DGR is that it is far below rather than far above the local water table, which makes long term water exclusion and long term access for safety confirmation, maintenance and material recycling prohibitively expensive.

4. Another significant problem with the OPG nuclear waste disposal plan is lack of recognition of reactor design changes that should be implemented by OPG and Bruce Power to minimize ongoing formation of low atomic weight isotopes with long half lives. OPG, Bruce Power, NWMO and CNSC personnel all need training in relevant reactor design alternatives.

5. It is my recommendation that the JRP reject the OPG proposed Bruce DGR as not meeting

environmental protection requirements and that the JRP instruct OPG and NWMO to choose an alternate DGR site in high density granite with storage vaults that are gravity drained and high above the local water table and hence are suitable for long term storage of nuclear wastes in a manner that safely and inexpensively permits monitoring, on-going inspection, maintenance and radioactive material recycling.

6. I further recommend that the JRP instruct OPG and Bruce Power to address use of a liquid sodium pool to prevent neutron degradation of reactor components that are subject to structural, pressure or erosion mechanical stress. These material degradation mechanisms trigger refurbishment and decommissioning costs and cause formation of avoidable refurbishment and decommissioning nuclear waste.

7. I further recommend that the JRP instruct OPG and Bruce Power to recover for resale to third parties the tritium/helium-3 that OPG currently plans to place in the proposed Bruce DGR.

8. I further recommend that very low level nuclear waste with no future recycling value be used to back fill depleted uranium mines instead of being placed in an expensive DGR.

9. I further recommend that future OPG DGR plans be guided by an individual who has real life experience with large scale rail transport of hazardous materials, so that the real risks relating to rail transport of nuclear waste are identified, quantified and properly addressed.

10. A major source of problems at OPG and the NWMO is lack of executive knowledge of both relevant physics and available physical and intellectual resources. There is zero knowledge by OPG and NWMO managements of the physics that determine the ambient temperature on Earth and hence determine the scope of future nuclear reactor construction in Ontario and the scope of the required supporting DGRs. There is almost no knowledge by OPG and NWMO managements about fast neutron transmutation work at AECL during the early 1960s, about fast neutron transmutation work at EBR-2 in Idaho during the period 1964 to 1994 and about current DGR relevant work in British Columbia and Alberta by both major mining companies and by parties associated with TRIUMF. TRIUMF is an association of western Canadian post secondary educational institutions and businesses involved in nuclear related work.

11. In order to resolve this knowledge gap I recommend that the NWMO offices be relocated to British Columbia (or possibly Labrador) where the geology is much more suitable than in Ontario for formation of a remote, high, dry and accessible DGR in granite and where there is an existing hard rock mining infrastructure for DGR formation and for bulk toxic material processing.

12. The idea of locating the DGR in Ontario may have to be abandoned because Ontario geology is poorly suited to safe accessible storage of radio isotopes. The NWMO concept of a "receptive community" must be abandoned because at any location that is suitable for nuclear waste storage there is insufficient ground water to support a permanent community.

13. It will be necessary to train and pay the nearby population for work related to the DGR. The minimum time required for this training is reasonably estimated by TRIUMF to be six years, so OPG needs to initiate this training program as soon as possible.