The Ethics of Nuclear Waste in Canada:

Risks, Harms and Unfairness.

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

The Nuclear Waste Management Organization (NWMO) — the crown corporation responsible for the long-term storage of nuclear fuel waste in Canada — seeks to bury our nuclear fuel waste deep in the Canadian Shield, with the provisions that the waste is monitored and remains retrievable for possible future use. To ensure that its solution is ethically acceptable, the NWMO established a set of requirements which, if satisfied, would successfully discharge its ethical obligations to both present and future generations. Those requirements include the obligation to justify its practice, minimize risk, clearly identify all of the relevant costs and risks of harm, abide by the precautionary principle, obtain fully informed consent from potentially affected individuals, and distribute the risk fairly across multiple generations. In this document I show that the ethical principles, as formulated by the NWMO, are either (a) seriously vague and unhelpful; or (b), where substantial and helpful, the nature of the practice show that many of the principles cannot be satisfied. As a final result, it is deeply questionable whether nuclear power in general, and especially the current solution to nuclear waste in particular, can ever be deemed ethical in Canada.

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Chapter 1

Introduction

> Just imagine: none of us will be here, not even our great-great-grandchildren. All our cities will have gone. ... Even the pyramids of Egypt will be just a handful of dust, yet the sarcophagus around this reactor of yours will still be standing. The pyramids of the pharaohs have been there for a mere five thousand years. But to contain the radiation your nuclear pyramid must remain for at least a hundred thousand years. (*Bitterly*) That's some monument to leave our descendants, isn't it? (Gubaryev, 1987, 87).[1]

Canada is poised for a renaissance of nuclear power development, due largely to commercial interests and renewed public concern for reducing our 'carbon-footprint' by using clean-energy sources that minimize our contribution to climate change (Bickerstaff et al., 2008). In this regard nuclear energy is touted as our saving grace — according to the Canadian Nuclear Association, nuclear power is "Clean, Reliable, and Affordable."[2] By 'clean' they mean that it is "North America's largest source of emission-free energy, which means *it emits no pollutants into the environment.* This keeps the air clean, prevents acid rain, and preserves the earth's climate and avoids

[1] This passage is uttered by the doomed character Bessmertny (the Russian word for 'immortal') in Vladimir Gubaryev's play "Sarcophagus." The story takes place in the immediate aftermath of the Chernobyl disaster.

[2] See <www.cna.ca>.

ground-level ozone formation." And, they continue, nuclear waste is managed in a "safe, environmentally responsible way."[3] In addition, our nuclear industry provides employment for 21,000 people. For these reasons Ontario Power Generation is planning to build at least two new reactors in Ontario, and Bruce Nuclear Power is seeking to build up to four new reactors in oil-rich Alberta in order to meet projected energy demands; these new reactors are in addition to twenty-two nuclear commercial reactors that are either in operation or undergoing refurbishment.

But this source of energy and the benefits it brings comes with a great cost — nuclear power generates tonnes of radioactive fuel waste that is irreversible, carcinogenic, and potentially lethal; moreover, once the waste has been created there is absolutely nothing that we can do to reduce its inherent toxicity except to isolate the waste and wait for the radioactive isotopes to decay into stable elements. Though 90% of the harmful radioactive isotopes will significantly decay within the first ten years after removal, the longer-lived isotopes must be secured from human and environmental contact for literally eons. One such dangerous radioactive isotope is plutonium, which will take about two hundred and forty *thousand* years before it fully transmutes into non-radioactive lead.[4] If a human or animal ingests this substance it will primarily concentrate in their soft tissues, liver, and bone marrow, the results of which are increased risk of specific cancers and even death; the lethal dose of plutonium for humans is about 27 *micrograms* of plutonium (27/1000 grams).[5]

From the inception of the Canadian nuclear industry in the 1940s, and the commencement of full-scale commercial nuclear operations in the 1960s, Canada now has approximately 119,000 *kilograms* of plutonium (and this is only one of the 200 newly created isotopes in each reactor) contained in approximately 1.7 *million* fuel bundles

[3] See <www.cna.ca/english/pdf/NuclearFacts/02-NuclearFacts-environment.pdf>

[4] Plutonium-239 has a half-life of 24,000 years. It will completely transmute into non-radioactive lead after approximately 240,000 years.

[5] This amount is contested, as there have been very few studies done on the health effects of plutonium. However, the U.S. Department of Energy's standard for the occupational air concentration of plutonium is 32 trillionths of a gram per cubic meter, and a total radiation exposure of 5 rem/year or less; "rem" stands for Roentgen Equivalent Man, and it is a unit of radiation dose, of which more will be said in the following chapters. See <http://www.atsdr.cdc.gov/toxprofiles/phs143.htm> and <http://www.clarku.edu/departments/marsh/projects/community/plutonium.pdf>.

of high-level nuclear waste, all of which are currently stored on-site at the various reactors (LLRWMO, 2004). A further 85,000 fuel bundles are produced *each year*, and the total number is expected to reach 3.6 *million* fuel bundles by the year 2033 if we continue to generate electricity using nuclear energy (Winfield et al., 2006, 81). Isolating this waste from humans and the environment for eons is a grave ethical and social problem. By any measure we need to be careful with how we manage such long-term and high-risk waste, and to proceed in an ethically responsible manner. Nothing less than our monument to the future — and the health and well-being of our descendants — is at stake.

The Nuclear Waste Management Organization (NWMO), the Crown corporation that owns all nuclear fuel waste in Canada, has proposed a so-called "Adaptive Phased Management" approach as Canada's solution to the long-term management of existing and commissioned nuclear fuel waste. This approach was presented to Parliament in November 2005 in a Final Study document entitled *Choosing a Way Forward: The Future Management of Canada's Used Nuclear Fuel Waste* (Nash & Dowdeswell, 2005a), and on June 14th, 2007, it was formally accepted as policy. This approach seeks to bury the waste deep in the Canadian Shield, with the provisions that the site is monitored and that the waste remain retrievable in case future generations wish to extract the fuel for reprocessing. (Reprocessing involves extracting fissile material from the waste to be used again as fuel in a nuclear reactor.) While Adaptive Phased Management (APM) has been approved, it is still incumbent upon us to ensure that it is indeed an ethically justified approach, especially since the storage site in the shield will not be finished for at least one hundred years. The need for such an evaluation has been made abundantly clear by the NWMO's Roundtable on Ethics[6] and its commissioned reports on nuclear waste ethics:

> we are a long way from having an acceptable social and ethical framework within which to discuss high level nuclear fuel waste management (NFWM). There has

[6]See <http://www.nwmo.ca/membersroundtableonethics> for a summary of the qualifications of each member of the Roundtable on Ethics.
For full documentation, see: <http://www.nwmo.ca/ethicalandsocialframework>.

> not been a great deal of work done on this issue in Canada. We do not have even a common vocabulary to talk about what is at stake; or agreement over the domain and range of the issues that should be discussed (Timmerman, 2003b).

The situation, unfortunately, had not changed by the time the Final Study was released:

> ...[the Roundtable on Ethics] was not able to conduct a detailed in-depth evaluation of the recommended approach and is therefore not in a position to say definitively that the recommendations set out the "least bad approach" or are in their entirety "ethically sound."[7]

This is a big problem. Though the NWMO claims adherence to the "highest ethical standards both in its procedures and in its assessment of management options" (Nash & Dowdeswell, 2005a, 369), this is not possible unless we specifically know what the ethical standards are, and whether they can be satisfied. We cannot proceed in an ethically responsible manner if we have neither a common vocabulary for the issues nor a justified ethical framework to inform our social and technical options for implementing a long-term nuclear waste storage facility.

In this dissertation I seek to remedy that serious defect, at least in part, by systematically evaluating the most crucial components of the NWMO's ethical framework for the long-term management of spent nuclear fuel waste. The principles of its framework are provided at the end of this Chapter; these four pages of principles — or suggestive questions, anyway — are taken directly from the 2005 Final Study, which was presented to Parliament for approval, and then adopted by Parliament as policy. A waste management solution that does not satisfy these crucial requirements — cost/benefit analysis and issues of harm and fairness especially — cannot be ethically acceptable, and so it is imperative that we both ensure that these are the right principles and determine whether or not they are being satisfied. **In this dissertation**

[7]See the Roundtable on Ethics meeting minutes, 8 June 2005.

I will show that the principles in question are either not being met or are not even satisfiable. I aim to convince the reader that the NWMO's ethical framework is not satisfactory, and therefore — crucially — **we do not in Canada have an ethically justified approach to the serious social problem of nuclear waste management**.[8] We will, as a matter of fact, burden future generations with our nuclear waste, but it will not be an ethically justified burden. The structure of my argument will take the form of critically evaluating the most important principles in the NWMO's framework to show how each principle fails to be met either upon conceptual clarification and/or putting the principle up against empirical evidence. Please note, however, that for reasons of exposition I will not always evaluate the principles in the order in which they are presented by the NWMO; the purpose of this re-ordering will become clear as we proceed.

The first social or ethical consideration that must be addressed is whether or not using nuclear power is a justified approach to meeting our energy demands (framework item Q5 below). The nuclear industry claims that its practise is justified if the benefits provided by the reactor (electricity, jobs, and clean environment) outweigh the costs of the operation (price of delivery, radiation, long-term waste storage), with the proviso that the radiation risk be kept "As Low As Reasonably Achievable." The proviso is further strengthened in Canada with the requirement that the industry *minimize risk of harm* to humans and the environment. This will supposedly be accomplished, in the case of nuclear fuel waste storage, by building multiple protective barriers to secure the waste; the barriers include concrete, steel, and deep emplacement in the tectonically inactive Canadian Shield rock. In Chapter 4 I will examine rigorously the content of this cost-benefit argument, and provide several reasons why it is unsatisfactory.

A cost-benefit analysis approach to justifying its practise, however, is no longer seen

[8] The Roundtable on Ethics, commissioned by the NWMO between 2003 – 2005, was acutely aware of the important and difficult ethical issues besetting any nuclear fuel waste disposal option, but the available time and resources do not appear to have been adequate for the Roundtable to completely develop a robust and precise ethical framework before the November 2005 deadline; or, alternatively, their recommendations were softened somewhat for the Final Study. One can find the full extent and depth of discussion by the Roundtable on Ethics in their Meeting Minutes, which can be found on the NWMO website.

as the only condition of ethical acceptability. In fact, the NWMO was established in 2002 to address the concerns raised by the 1998 Seaborn Report, an important study which found that the technical solution of deep geological disposal was the best option under the constraint of minimizing long-term risk to human health, but that it still remained publicly unacceptable because the social and ethical conditions of acceptability remained unaddressed. That is, a cost-effective technical solution unconstrained by social and ethical considerations is not sufficient for a publicly acceptable solution to the long-term problem of nuclear fuel waste management. The NWMO's social and ethical frameworks are intended to specify the nature of these further requirements; in this document I only address the ethical framework explicitly, but some of the requirements for both frameworks extensively overlap. Broadly formulated, the ethical principles or requirements that the NWMO says it must satisfy include the following:

> [demonstrate] respect for life in all its forms, including minimization of harm to human beings and other sentient creatures; respect for future generations of human beings, other species, and the biosphere as a whole; respect for peoples and cultures; justice (across groups, regions, and generations); fairness (to everyone affected and particularly to minorities and marginalized groups); and sensitivity to the differences of values and interpretation that different individuals and groups bring to the dialogue (Nash & Dowdeswell, 2005a, 366).

The other framework items under consideration include the requirement that people who may be exposed to the risk give their informed consent; that the NWMO act according to the best available information; that the NWMO honestly admit where gaps of knowledge or uncertainty reside in its models; and that it fully disclose the true costs and harms involved. In Chapter 4 I will evaluate these ethical principles (or requirements) and provide reasons why each of them fail, as formulated by the NWMO, to be satisfied or even satisfiable.

In Chapter 5 I will address one of the main requirements that the NWMO takes to be an overriding ethical consideration, namely, that it distributes the risk of harm *fairly.* Indeed, the NWMO claims that the APM approach offers the fairest distribution of costs and benefits across multiple generations:

> As a blend of a flexible centralized storage facility over the next 300 years, coincident with an extended period of proof of concept activities, and final placement of used nuclear fuel in a deep repository, this approach is judged to provide the fairest distribution of benefits and risks within this generation and across generations (Nash & Dowdeswell, 2005a).

But how can we distribute nuclear waste *fairly* across multiple generations, especially when future people will receive all of the burden and none of the direct benefit?[9] I will argue that the NWMO takes a Rawlsian approach to fairness, and aligns its fairness conditions in accordance with his maximin principle. That is, any siting procedure and safety measures of a repository should not unduly disadvantage the least-advantaged members of the society or community. Thus, the NWMO claims that it distributes the risk fairly if: (a) present users pay for the full cost of disposal; and (b) it 'respects nature and future generations.' I will examine the content of this claim and show that it cannot be satisfied, due largely to the problems that also beset the other principles — technical and political uncertainty, lack of informed or voluntary consent, and the nature and irreversibility of the harm in question. We *will* distribute the radioactive burden, but we will *not* distribute it fairly.

Finally, I want to familiarize the reader with one of the most important issues that currently besets the nuclear debate:

> Since "something" has to be done with the [existent] wastes, a least-bad solution is morally acceptable if that is the best there is. Whereas for [the] creation

[9] *Direct benefits* include electricity, jobs, and economic stimulation. *Indirect benefits* are those benefits which are said to have resulted from our developements aided by nuclear-generated electricity, such as new innovations and a higher standard of living. Indirect benefits are included in arguments for nuclear power because it is believed that future people will be better off than they would be if we did not use nuclear-generated electricity. The biggest issues, however, are whether the risk imposed is worth the indirect benefits, and whether the indirect benefits could have been accrued using a safer and more environmentally friendly means of electricity generation.

> of new wastes to be morally acceptable, there must be not just a least-bad management solution, there must be a genuinely good solution.[10]

It is quite apparent that we must do something with the waste which we have already generated; and for this the best that we can probably hope for is that we minimize possible risks and accept the 'least-bad' solution. Adaptive Phase Management might provide us with the least-bad option, even though it is not fully good. Under these circumstances it might be acceptable as the lesser of all possible evils. However, stricter requirements are needed for the generation of new waste (i.e., commissioning new nuclear reactors). As the NWMO states, "for the creation of new spent fuel to be ethically justified, it would have to be shown that there exists a management option that is ethically sound, not just least bad" (Nash & Dowdeswell, 2005a). Despite the fact that the NWMO is not mandated to consider the future of nuclear energy, the Roundtable on Ethics insists that generating more nuclear waste cannot be separated from the ethical framework: "It is very important ethically that NWMO address the future of nuclear energy. Whether it is written in the mandate is really of no consequence."[11] Quite simply, without an ethically acceptable solution regarding storage we are not justified in commissioning and producing more radioactive waste through nuclear power. Thus, a profound ethical question-mark hangs over the entire practise of nuclear power in Canada.

[10] Roundtable minutes 17 November 2004. See also (Brook et al., 2005).
[11] Roundtable minutes 17 November 2004.

"Ethical and Social Framework" Suggested by Roundtable on Ethics

The "Ethical and Social Framework", as drafted by the Roundtable on Ethics, is reproduced in its entirety below. The NWMO suggests that this framework receive further consideration by the NWMO and Canadians for the guidance it may provide concerning the implementation of the management approach selected by the Government of Canada.

"Ethical and Social Framework" Suggested by Roundtable on Ethics

March 4, 2005

Nuclear Waste Management Organization Roundtable on Ethics

The Roundtable on Ethics has developed the following Ethical and Social Framework within which to consider the management of spent nuclear fuel, as was recommended by the Environmental Assessment Panel in its report to the federal cabinet. The Roundtable recommends that the NWMO adopt this framework, publish it in NWMO documents and on the NWMO website, and conduct its activities in the light of it. The Roundtable may refine the framework further as the work of the NWMO progresses.

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Ethical and Social Framework

Recognizing that everyone contributing to the NWMO's work seeks to use procedures and make recommendations that are ethically sound, NWMO commits itself to embed ethics in all its activities. The aim is to ensure that its work, its ultimate recommendations, and their implementation reflect the highest ethical standards. To assist NWMO in achieving its ethical goals, the Roundtable on Ethics has constructed a framework of questions designed to guide its deliberations and its ultimate recommendations. These questions aim to identify basic values, principles, and issues.

The ethical principles incorporated in the framework include: respect for life in all its forms, including minimization of harm to human beings and other sentient creatures; respect for future generations of human beings, other species, and the biosphere as a whole; respect for peoples and cultures; justice (across groups, regions, and generations); fairness (to everyone affected and particularly to minorities and marginalized groups); and sensitivity to the differences of values and interpretation that different individuals and groups bring to the dialogue. These principles apply both to the consultative and decision-making procedures used by NWMO and to the recommendations that it will make.

Given the large stockpile of highly radioactive spent fuel that already exists or will be created in the lifespan of existing reactors and that will be hazardous for thousands of years, some solution to managing this material as safely and effectively as possible must be found.

The goal is to find and implement an ethically sound management approach. However, if no ethically sound management approach exists, adopting the ethically least-bad option available to deal with existing and committed spent fuel would be justified.

By contrast, the creation of new spent

fuel (that is, beyond what already exists or will be created in the lifespan of existing reactors) and, thereby, the issue of its disposal, must be judged by the standard of full ethical soundness. If the best current proposal does not meet this standard, then it would not be justified to create new material. To justify creating new spent fuel from an ethical point of view, there must be a management solution that is ethically sound, not just least bad. (The other ethical issues associated with nuclear power generation would have to be resolved, too, problems such as the effects of uranium mining and mine tailings, vulnerability of spent fuel to terrorist attacks, safety of the reactors, danger of diversion for nuclear weapons, and whether increased nuclear power generation can be justified, given the available options.) Moreover, even a least-bad option acceptable for the existing problem might cease to be acceptable if there were changes in the nature of the spent fuel, such as adding spent enriched fuel.

In short, a solution that is ethically acceptable for dealing with existing spent fuel is not necessarily a solution that would be ethically acceptable for dealing with new or changed materials. Thus, a question that urgently needs to be addressed is whether NWMO is dealing simply with existing materials and those that will be created in the lifespan of existing reactors or also with substantial additional spent fuel? And this is no less than the question: What will the future of nuclear power in Canada be?

Ethical Questions Relevant to the NWMO's Procedures

Some of the questions that arise concerning procedures are:

- Who should participate in the decision-making process?
- What principles should guide consultations, deliberations, and the making of decisions?
- When facts are in dispute or unavoidably uncertain, how should NWMO proceed?

These general questions give rise to more specific ones. The list of questions that follow is not meant to be exhaustive. For each question, the principle(s) involved is/are in boldface type.

Q1. Is NWMO conducting its activities in a way appropriate to making public policy in a **free, pluralistic, and democratic society**? In particular, are its activities **open, inclusive, and fair** to all parties, giving everyone with an interest in the matter an opportunity to have their views heard and taken into account by NWMO? Are groups most likely to be affected by each spent fuel management option, including the transportation required by some of the options, being given full opportunity to have their views heard and taken into account by NWMO? Is NWMO giving special attention to aboriginal communities, as is mandated by the governing legislation?

Q2. Are those making decisions and forming recommendations for NWMO **impartial**, their deliberations not influenced by conflict of interest, personal gain, or bias?

Q3. Are groups wishing to make their views known to NWMO being provided with the **forms of assistance** they require to present their case effectively?

Q4. Is NWMO committed to basing its deliberations and decisions on the **best knowledge**, in particular, the best natural science, the best social science, the best aboriginal knowledge, and the best ethics – relevant to the management of nuclear materials, and to doing assessments and formulating recommendations in this light? Equally, have limits to the current state of knowledge, in particular **gaps** and areas of **uncertainty** in current knowledge, been publicly identified and the interpretation of their importance publicly discussed and justified?

Q5. Does NWMO provide a **justification** for its decisions and recommendations? In particular, when a balance is struck among a number of competing considerations, is a justification given for the balance selected?

Q6. Is NWMO conducting itself in accord with the **precautionary approach**, which first seeks to **avoid harm and risk of harm** and then, if harm or risk of harm is unavoidable, places the burden of proving that the harm or risk is ethically justified on those making the decision to impose it?

Q7. In accordance with the doctrine of **informed consent**, are those who could be exposed to harm or risk of harm (or other losses or limitations) being **fully consulted** and are they willing to accept what is proposed for them?

Ethical Questions Relevant to NWMO's Recommendations

As before, key ethical principles are in boldface type.

Q8. Do NWMO's recommendations reflect **respect for life**, whatever form it takes, wherever it occurs, and whenever it exists (now and into the foreseeable future)? In particular, are NWMO's recommended solutions likely to protect human beings, including future generations, other life forms, and the biosphere as a whole into the indefinite future?

Q9. Is a reasonable attempt being made to determine, in so far as it is possible to do so, the **costs, harms, risks, and benefits** of the options under consideration, including not just financial costs but also physical, biological, social, cultural, and ethical costs (harm to our values)?

Special ethical issues arise with respect to risk assessment in the nuclear industry. For example, might some scenarios be so horrendous that even a slight risk of their occurrence would be morally unacceptable or unacceptable by Canadians?

Q10. If implemented, would NWMO's recommendations be **fair**?

This question breaks down into a number of sub-questions:

Are the beneficiaries of nuclear power (past, present and perhaps future) bearing the costs and risks of managing spent fuel and other nuclear materials in need of treatment? Do the recommended provisions avoid imposing burdens on people who did not benefit from the activities that created the spent fuel?

Are costs, risks, and benefits to the various regions affected by the use, possible transport, and disposal of the materials being distributed fairly?

Are the interests of future generations and nonhuman life forms being respected?

Are the rights of individuals and minorities being respected, especially vulnerable individuals and minorities?

Q11. Do the recommended provisions protect the **liberty** of future generations to pursue their lives as they choose, not constrained by unresolved problems caused by our nuclear activities? Do the recommended provisions maximize the range of choice open to future generations?

Important Specific Issues
In connection with Q8 to Q11, at least four specific issues merit special consideration.

1. Monitoring, remediation, and, if needed, reversal. Are sound provisions being made to check on whether management provisions are working as designed? If problems appear, are provisions being made to gain the access needed to fix them? Is the issue of reversal if something goes seriously wrong being taken into account?

2. Risk reduction vs. access. What is the appropriate balance between reducing risk to the greatest extent possible and retaining access to the materials, for remediation, for example, or to recover valuable materials from them?

3. Permanent or interim? Is it ethically acceptable to seek a permanent solution now or would it be preferable to recommend an interim solution in the hope that future technological improvements might significantly lower the risks or diminish the seriousness of the possible harms?

4. Lessons to be learned. What lessons can we learn for the future of the nuclear power generation industry from the problem of management of spent fuel and the NWMO's efforts to resolve it?

In closing, we will repeat a point made earlier. Because we must manage already-existing and already-committed spent fuel in some way, here the least-bad option is an ethically acceptable option. By contrast, new spent fuel – whether generated by new reactors, by replacing existing reactors as they reach the end of their serviceable life, or by importing material from other countries – is ethically another matter altogether. For the creation of new spent fuel to be ethically justified, it would have to be shown that there exists a management option that is ethically sound, not just least bad. (Other ethical issues to do with nuclear power generation such as the ones mentioned above would have to be resolved, too.)

In its final review of the *Draft Study Report*, the Roundtable endorsed the NWMO's recommendation as a way to manage current and currently-planned used nuclear fuel, which was the scenario at the focus of their deliberation.

They strongly emphasized that their acceptance of the recommendation for the treatment of that waste must be distinguished from the treatment of any "new" waste. The ethical standards that should be applied to deal with waste from existing fuel and those that would apply to the generation of waste as a result of a decision to expand nuclear power or to continue production beyond facilities' current lifespans are not the same. Endorsement of this recommendation for current and currently-planned used fuel should, therefore, *not* be taken as endorsement of this approach for a scenario in which new used nuclear fuel is produced. A scenario of new used nuclear fuel was not considered by the Roundtable.

Chapter 2

Framing the Ethical Issues

Nuclear power involves a complex set of technical, social, and ethical concerns. Such an applied issue naturally poses particular difficulties, as the knowledge and limitations from each respective specialized field needs to find some communicative ground if each is to contribute meaningfully to Canada's solution to the problem of nuclear fuel waste management. The scientific and engineering knowledge about which is the preferable method of storing radioactive waste over the long-term must be balanced with a set of social and ethical concerns, such as: how much risk of exposure to harm is acceptable? How should the risk of harm be distributed among the population? Is the siting process fair? Is nuclear waste creation a justified practise? Should informed consent be obtained from a host community? What is an acceptable level of uncertainty regarding the long-term behaviour of radioactive storage methods? Who is responsible if the repository leaks its waste? Are we imposing an unacceptable risk upon future generations? Do we even have any obligations to future people, and if so, what is the nature of such an obligation? The answers to these questions, and more, should be provided by a document which offers arguments for why and how the NWMO ought to proceed in these regards.

Unfortunately, the Nuclear Waste Management Organization's (NWMO) ethical framework is a conceptual mess. It offers only vague and unsatisfiable questions, and no clear principles or ethical argument for how we should manage our nuclear fuel wastes. Yet it is this deeply flawed document — approved by the Canadian Parliament — which represents Canada's putative ethical position on the matter. It is woefully unacceptable, and the time has not yet passed for a full re-evaluation before construction begins on the repository. What we need is a coherent and sophisticated ethical position on what constitutes an ethically acceptable solution for the long-term management of Canada's nuclear fuel waste, and only then can we evaluate whether a given proposed repository is ethically acceptable. Before such a position can be developed, however, it must be shown that the current framework is unworkable. In this dissertation I take steps toward that end by critically examining the NWMO's "ethical framework," as it was adopted by Parliament in 2005, and I will show that the key ethical issues, as formulated by the NWMO, have *not* been (and some *cannot* be) satisfied.

In this chapter I discuss an overarching philosophical concern with NWMO's approach, namely why it has adopted what it calls an "ethical framework" as opposed to an approach based upon a particular ethical theory. I will also address some of the difficulties involved in 'framing' two key ethical issues which are central to this thesis, namely the ethical issues of *justification* and *distributional fairness*; the details of these issues will be addressed in their respective chapters.

2.1 What is an Ethical Framework?

The Nuclear Waste Management Organization (NWMO) has created what it calls an "ethical framework" which, it claims, provides the requirements for an ethically justified solution to nuclear fuel waste.[1] What, then, is an ethical framework? (And, as I will address shortly, why use the word 'framework' instead of 'theory'?) We should expect a definition early in the NWMO's document, but what we are offered is

[1] The full set of 'requirements' (or questions, or rules, or principles, or suggestive queries) is contained at the end of chapter 1.

anything but clear. The NWMO claims that the aim of its ethical framework is

> . . . to ensure that its work, its ultimate recommendations, and their implementation reflect the highest ethical standards. To assist NWMO in achieving its ethical goals, the Roundtable on Ethics has constructed a **framework of questions** designed to guide its deliberations and its ultimate recommendations. These questions aim to identify basic values, principles, and issues (Nash & Dowdeswell, 2005a, emphasis mine).

We are thus presented with the idea that its ethical framework is a set of questions which will *guide* its deliberations. But a guide does not create or impose any ethical obligation on the organization's actions, as one would expect. Any ethical system or theory (I use these terms loosely for the moment) must, at the very least, establish what constitutes good or right action between individuals or between groups of individuals; some recent ethical theories have also been extended to include a specification of what constitutes the proper action or relation between individuals and the natural environment. A set of questions, however, makes no such specification in either of these regards — either between individuals, or between individuals and the environment. Perhaps the NWMO realizes this as it states, in the next paragraph, that:

> The **ethical principles** incorporated in the framework include: respect for life in all its forms, including minimization of harm to human beings and other sentient creatures; respect for future generations of human beings, other species, and the biosphere as a whole; respect for peoples and cultures; justice (across groups, regions, and generations); fairness (to everyone affected and particularly to minorities and marginalized groups); . . . These principles apply both to the consultative and decision-making procedures used by NWMO and to the recommendations that it will make (ibid., emphasis mine).

An ethical framework, as they have adumbrated, is now *both* a set of questions and a set of principles. But nowhere in the framework do we actually get a clear statement of any particular principle. Rather, the first articulation holds sway and we are only presented with a set of questions, not principles. For example, item five reads as follows:

> Q5: Does [the] NWMO provide a justification for its decisions and recommendations? In particular, when a balance is struck among a number of competing considerations, is a justification given for the balance selected? (Nash & Dowdeswell, 2005a).

Since the NWMO vacillates between giving the appearance of a principled approach (while they only offer non-committal questions), I have had to reformulate and distill each question into a particular requirement (or 'principle') of action; at this stage we might also call such requirements ethical obligations. This is an important first step. To evaluate whether or not nuclear power is ethically acceptable, we need to know whether or not the NWMO has fulfilled its ethical requirements; and in order to make this determination, we first need to know — to a reasonable degree of clarity and precision — what those requirements actually are. So, for example, before we can begin to analyze item Q5, it must first be reformulated from the interrogative into a proposition which requires action (or the cessation of action) on the part of the NWMO. For example, Q5 should tentatively read as follows:

> Q5: The NWMO must justify its decisions and actions.

Even this formulation makes evident the ensuing difficulties of establishing such a requirement. What does it mean by 'justification'? How can the NWMO successfully justify its actions? What is meant by 'actions'? These questions need principled answers, and a reasonable ethical framework will specify clear *answers* to these questions, not merely pose them. This procedure is then applied to the remaining items — or questions — in its ethical framework so that we will have a manageable basis point for determining whether or not the NWMO is, or even can be, acting in an ethically acceptable manner or implementing an ethically acceptable solution. (The full ethical framework from the Final Study (2005) is at the end of chapter 1.) By way of a further brief example, its question "Q10: If implemented, would NWMO recommendations be fair?" is tentatively reformulated to "Q10: The NWMO must distribute the risk of harm from nuclear fuel waste *fairly* across multiple generations." It is obvious that we now need to ask what is meant by 'fairness'? Can fairness apply across multiple generations? And how can risk be fairly distributed, even among the *present* generations?

This is the pattern of analysis which I have adopted for this document. I do not, however, analyze every single question in the NWMO's published ethical framework. Rather, I have chosen to analyze what I take to be the most important or relevant ethical issues presented by the NWMO; the remaining issues are either given shorter attention or else subsumed under a previous question. The main ethical issues upon which I focus attention are given their own chapter, such as justification (chapter 4) and distributional fairness (chapter 6), while the issues of informed consent, precautionary principle, incorporating uncertainty, and respecting nature are given significant but shorter treatment (and have been collectively placed in chapter 5).

2.1.1 Framework vs. Theory

Why has the NWMO adopted the term 'framework' instead of 'theory'? Though the NWMO does not offer an explicit reason for this choice of terminology, I think that there are some plausible reasons which may have directed their rationale for making this choice. An ethical theory — such as deontology, utilitarianism, rights-based or virtue ethics — offers the basis for good or right conduct independently of an applied context. That is, the proscriptions and limitations of action dictated by an ethical theory hold across a range of human (and possibly human-environmental) interactions. For example, an utilitarian will argue that an action is good if its consequence leads to an increased net-benefit (or happiness), while the best action is one that leads to the greatest net-benefit (or happiness) in relation to possible alternative actions. This dictum holds regardless of particular circumstances and, if we are to be consistent, it should be applied to each of the ethical problems — such as fair distribution, respecting nature, justification of practise, and informed consent — which beset the nuclear power issue. The task, then, is to justify and apply a given ethical theory. But this type of approach is not recommended by the NWMO. There are many issues to take into consideration, and it is doubtful that we will find a single ethical theory that will address the important ethical problems at issue in a publicly acceptable manner. For instance, if we follow a standard utilitarian risk distribution scheme, then it would be morally acceptable to impose a large burden of risk on a relatively small portion of the population — like a small Ontario community — so long as such a distribution clearly benefits most people (as it would). But such a scheme would be *publicly unacceptable* without non-utilitarian constraints like the requirement for informed consent, adopt a user-pays policy, respect nature, and the requirement to minimize risk. Thus, users of nuclear power hold several values to be important — radiation safety over long-time periods, jobs, profit, option for reprocessing, respect for nature, and fair risk distribution. Unfortunately these values are not all comparable (e.g., how does one reconcile 'respect for nature' with utilitarianism?), and so in order to incorporate the main values the NWMO has divided the ethical issue of nuclear waste management into sub-domains, and offers particular ethical solutions for the respective problems under the rubric of its ethical framework.[2]

Unlike an ethical theory, an ethical framework *frames* the issues in a particular manner and context — it establishes what shall be considered legitimate problems, what constitutes a good solution to a given problem, and what is to be considered outside the purview of the framework. For example, the NWMO claims that the distribution of risk across multiple generations is a relevant problem, and that the right solution is to distribute risk *fairly* (as opposed to another distributional solution). The task then

[2]The values espoused by the NWMO were adopted through deliberations by the Roundtable on Ethics and the recommendations from public forums on nuclear waste management held between 2003 – 2004.

is to define and calculate the relevant risks, and define what is meant by fairness. Thus, a framework gives us an applied context with stipulated boundaries for the chosen ethical solutions. We need to ask, of course, whether all of the ethical issues been properly identified and articulated. Why has a given solution been proposed or adopted and not another? And what is the *justification* for such a solution? These are very serious questions. To say that an approach is ethically acceptable, all of the important and relevant ethical concerns should *presumably* be addressed. We know that this is not yet fulfilled in this instance. By its own arbitrary delineation, the NWMO has stipulated that issues of what to do with future waste are not to be included under the purview of its ethical system; that is, it has framed the debate in such a way as to exclude concerns about *future* nuclear fuel waste, focussing only on existing waste. But the former issue is clearly relevant if Canadians embark on a programme to expand nuclear power, and the issue should therefore not be eliminated from any reasonable framework.

In this dissertation I acknowledge that some ethical issues have been excluded, but I believe that sufficient analysis can be performed on the major recognized issues to show that the existing ethical framework is gravely deficient. Now, once the relevant issues have been outlined (as they have been posed in its set of framework questions), the second difficulty for a pluralistic approach is to determine whether a particular ethical solution is the right one in the given context. For example, the justification of nuclear power is largely utilitarian — lots of benefits for lots of people — while the informed consent, respect of nature, and other ethical requirements are given distinctly non-utilitarian solutions (at least as offered by the NWMO). Why is this the case? How should we select which ethical theory to apply to any given problem? The NWMO does not, regrettably, offer any philosophical justification for its selection of ethical theories or approaches. We are asked to simply take them as they are presented. This will not stand up to scrutiny in a fully worked out approach, but for the document herein I leave this objection to the side and instead parse the various approaches used, and offer some possible reasons as to why the NWMO chose a given theory over another for each significant ethical problem.

2.2 On Justification: A Preview

The bulk of this thesis concentrates on two large ethical problems in the NWMO's ethical framework, namely the justification of a proposed solution and the requirement to distribute the risk 'fairly' across multiple generations. I have chosen these two central problems because, in part, they seem to me to undergird the NWMO's entire approach (at least rhetorically), and therefore offer a reasonable starting point for a larger re-analysis of their ethical framework.

Let us assume that "Q5: The NWMO must justify its actions ...." By this they mean that they need to give reasons for choosing one approach or action for waste management over another. From what I can derive from their documents, an action or approach is justified in their framework if it is the "least-bad" or "least-risky" approach. That is, 'justification' rests on an appeal to least-risk; the NWMO offers no further account of justification. As it states:

> The goal is to find and implement an ethically sound management approach. However, if no ethically sound management approach exists, adopting the ethically least-bad option available to deal with existing and committed spent fuel would be justified (Nash & Dowdeswell, 2005a).[3]

But there are two clear problems that need attention regarding the NWMO's version of justification. First, how do we know that we have chosen the "least-risky" solution among all of the possible alternatives? Have all of the possible alternatives been explored? The NWMO only examined four alternative options — keeping waste at on-site, shallow storage, permanent deep geological disposal, and deep geological disposal with options for retrievability and monitoring (called Adaptive Phased Management, or APM). While APM may be the least-risky of the alternatives presented, there

[3]The quote continues, "By contrast, the creation of new spent fuel (that is, beyond what already exists or will be created in the lifespan of existing reactors) and, thereby, the issue of its disposal, must be judged by the standard of full ethical soundness." The justification for *existing* waste management is *not* the same as the justification for producing new and future nuclear fuel waste.

may be better alternatives as-yet uninvestigated.[4] This is therefore a weak form of justification. Just because a solution is least-bad does not make it good; it could be simply the best of the bad solutions.

Second, the NWMO has neglected to acknowledge the issue of nuclear waste management in the broader context of nuclear power production. In fact, the NWMO has cleaved — or *framed* — the two issues as if they could be conceptually separated. This is not reasonable. Suppose that we have found that APM, or any approach, is indeed the least-bad solution, but that its cost is prohibitively expensive so as to make the cost of nuclear-generated electricity uneconomical. On the basis of least-risky justification, such an uneconomical approach would be the only justified option. But costs play a significant role in justification. The real solution lies in balancing risk or safety factors with the cost of the implementation of a waste management solution — that is, a complex cost-benefit analysis is performed, and this undergirds much of the justification of nuclear power and nuclear waste management. No activity is perfectly safe, so the goal, in rough terms, is to find an acceptable degree of safety for a reasonable cost. But the issue is not simply a matter of measuring costs and benefits. Rather, there is a non-financial principle incorporated as well, namely that a maximum threshold of risk-exposure not be exceeded under normal operating conditions; no amount of utilitarian net-benefit considerations can over-ride this principle. And so we have a clear instance of a pluralist approach to solving an ethical problem here (i.e., how much exposure is acceptable, and for what cost?). In chapter 4 I examine this complex ethical problem in more detail, and give a reasonable account of how a cost-benefit analysis is incorporated with the risk-threshold limit. The result of this investigation is that we need further analysis into full-disclosure of the actual costs and benefits involved in nuclear power (and nuclear waste in particular), and further studies on the health effects of radiation before we can determine whether or not a nuclear waste solution is justified. One result of this investigation will be that we need further analysis into full-disclosure of the actual costs and benefits involved in

[4]In fact, APM may not even be the least-risky of the options, since keeping the waste retrievable means that it is accessible, and such access always leaves open the option for tampering or retrievability for nefarious purposes.

nuclear power (and nuclear waste in particular), and further studies on the health effects of radiation before we can determine whether or not a nuclear waste solution is justified.

2.3 On Fairness: A Preview

The NWMO makes the claim that "[g]iven the nature of the hazard, it is imperative that we consider matters of "equity" or fairness within the current generation and future generations" (Nash & Dowdeswell, 2005a). Distributing the risk fairly, then, is an important ethical problem which must be addressed. The NWMO does not, however, offer a sustained philosophical argument supporting its requirements in this regard. Instead, we are presented with a set of guidelines for what constitutes fairness in two domains, namely what it calls 'substantive' and 'procedural' fairness. For substantive fairness, the NWMO suggests that it has met this obligation when it: (a) ensures that the users of electricity from nuclear power pay for the cost of disposal or management of the high level nuclear fuel waste; (b) that it distributes the costs, risks, and benefits fairly; and (c) shows what it calls "respect" for the interests of future generations and non-human life forms. Of course these are not stated as principles in the NWMO, but rather as questions to consider; I have reformulated them as requirements. Even so, the NWMO offers no justification for — no *reasons why* — fair distribution is the right course of action. Instead, we are lead to believe by stipulation alone that an action is fair so long as the "user pays" (also called polluter-pays) and "respects nature." That is, creating waste is permissible so long as the user pays for its disposal and management. Thus, the converse yields the implication that an action or solution would be unfair only if non-users (of nuclear-generated electricity) had to pay for the management or disposal of the nuclear fuel waste; those non-users could be either present or future generations. Added to this is the further requirement that the NWMO "respects nature." No guidance is offered on what this means, but presumably the NWMO holds that its approach would also be unfair if its implementation did not respect nature. I will return to this in a moment.

The general concept of fairness in the ethical framework is quite complex. In addition to the "user-pays" requirement, it is stretched to include matters of, in the words of the NWMO, *procedural fairness*. Procedural fairness includes a set of vague guidelines which are intended to convey the idea that the repository selection process should be a fair process. The catch-phrases employed include: full participation, participatory decision making, full information disclosure, and opportunity for the public to influence decision outcomes. The purpose of invoking these notions of fairness is to secure public trust in selecting and building a repository. Moreover, if public trust can be gained for *existing* waste, then it is likely that there will be little opposition to the creation of *new* nuclear fuel waste incurred by an expansion of nuclear power in Canada. But again, these concepts are not given a full explanation in the Final Study document, so we are left with the terms and little else.

Despite the fact that substantive fairness and procedural fairness appear disparate at first glance — the former is a general guideline for cost absorption, while the latter concerns matters of repository selection — I believe that they share a common philosophical foundation. Let us ask: in what theory is the fairness condition grounded? Where does this presumption of fairness come from? Although we are given no guidance in this regard by the NWMO, I argue that their general position on fairness likely derives from the very influential notion of fairness developed by John Rawls in his 1971 book *A Theory of Justice*. The details of his approach are provided in chapter 6. In part, he provides justification for the idea that we ought to

> identify the worst outcome of each available alternative and then adopt the alternative whose worst outcome is better than the worst outcomes of all the other alternatives (Rawls, 1971).

This is in line with the NWMO's claim that it must adopt the "least-bad" solution. A good implementation of this idea would also likely satisfy the "minimize risk" requirement. Rawls' maximin principle is also relevant to the procedural fairness conditions, namely that social and economic inequalities ought to be arranged such that "they are to be of the greatest benefit to the least-advantaged members of society" (Rawls, 1971). The inequality here is potential exposure to radioactive fuel waste, and the benefit provided is financial compensation commensurate with, or greater than, the risk borne. The NWMO aims to ensure, in compliance with its procedural fairness options, that a potentially willing repository community is aware of the risk, and that they are not duped into accepting the site either under pretense of false information or from financial coercion. If the process is procedurally fair, then the site selected is deemed to have been done in a fair manner. Thus, fairness involves a set of requirements: user-pays, minimize risk (choose the least-bad option), ensure the full disclosure of relevant information, obtain community consent, and offer appropriate compensation. In chapter 6 I will offer an analysis critical of the substantive fairness claims.

2.4 Conclusion

The NWMO's ethical questions — posed in its 'ethical framework' — have been put forward as practical guidelines which are likely to yield public support, and are not derived from a consistent philosophical or ideological argument. However, given the plurality of values involved, and the unlikelihood that a unified theory would be agreed upon, the framework option is the best approach at present. But the crucial fact remains that the NWMO has posed the elements in their ethical framework as vague questions, and this means that we do not have any formal solutions to the ethical issues of nuclear fuel waste. We therefore need to re-evaluate the situation to develop a coherent and meaningful ethical solution. In this dissertation I take on the first step — the destructive task — toward such an end by demonstrating how the NWMO's treatment of the most important ethical issues is utterly inadequate and in doing so I offer further understanding of the complexity and depth of the ethical issues involved.

One final consideration is worth raising regarding the use of an ethical framework. As I mentioned in earlier in this chapter, an ethical framework serves the purpose of framing the issues of stipulating the adopted solutions to the ethical issues within that framework. But by framing boundaries of what can and cannot be considered we leave open the possibility that legitimate ethical concerns are excluded. One such issue is the NWMO's arbitrary separation of the ethical issues pertaining to nuclear power (nuclear waste production) from nuclear fuel waste management (the territory of the NWMO). These two *cannot*, in reality, be separated, and the NWMO's own "user-pays principle" belies this distinction. According to 'user-pays' (or polluter-pays) principle, it would be unfair to place the financial burden for a repository on anyone who does not use, or has not used, nuclear-generated electricity. The "user" stage, however, is firmly in realm of nuclear power generation, and precedes waste management, and thus by its own admission the issue of nuclear waste management *cannot* be wholly separated from nuclear waste production. This admittance alone requires that we begin anew on the task of developing an ethical framework for nuclear waste management, as the current version is both unmanageably vague and the boundaries improperly defined.[5]

[5] After writing this dissertation I now hold the belief that any reasonable ethical account of nuclear waste management must be part of a larger ethical discussion on the ethics of nuclear power; that is, an ethic of nuclear power will subsume an ethic of nuclear waste, as they cannot be framed separately.

Chapter 3

Radioactivity and Adaptive Phase Management

> Nuclear fuel waste remains a potential health, safety and security hazard for many thousands of years, so the relative performance of any option must look out to these geological time frames. Any decision taken today will be implemented over a number of decades, at least. Undoubtedly the program will encounter major changes in science and technology, institutions, values, political perspectives, and economic and financial considerations (Nash & Dowdeswell, 2005a, 18).

There are two related types of radioactive processes involved in the production of nuclear energy: neutron-induced fission and radioactive decay (spontaneous fission). Neutron-induced fission is the process of splitting a fissile isotope (like uranium-235) by bombarding it with a neutron; the results of this fission reaction are lighter elements, potentially harmful radiation, and enormous amounts of heat. In all nuclear reactors, the heat generated from this reaction is used to boil water, which subsequently generates steam which is used to turn a turbine, and ultimately generate electricity. Most of the lighter elements produced by this fission process, however, are themselves radioactive, and they decay spontaneously at a rate particular to each isotope. (A radioactive isotope is, fundamentally, an unstable atom.) The decay process essentially involves an atom 'breaking apart' spontaneously (i.e., without external influence), resulting in even lighter elements, more radiation, and of course more heat. Ideally, we would like to keep the newly-produced unstable atoms inside the reactor until all the energy has been 'burned or absorbed,' but unfortunately they start to impede (or 'poison') the efficiency of the neutron-induced chain reaction needed to operate the nuclear reactor effectively.

When the fuel is removed, after about 18 months in a Canadian CANDU[1] reactor, it becomes used nuclear fuel waste. Over 200 new radioactive elements are created inside the reactor during its ordinary processing, making the resulting uranium fuel "a billion times more radioactive than its original inventory. A regular 1,000 megawatt nuclear reactor contains an amount of long-lived radioactive isotopes equivalent to that released by the explosion of 1,000 Hiroshima-sized bombs" (Caldicott, 2006, 54). The standard procedure in Canada is to store the waste in canisters completely submerged in water for seven to ten years. After that time, once the short-lived isotopes have decayed and most of the heat has dissipated, the waste is moved to an actively air-cooled facility. At present all nuclear fuel waste in Canada is stored on-site at the reactor. The long-lived isotopes (with decay-rates on the order of hundreds, or thousands, of years) still pose a potential hazard to humans and the environment, so the remaining waste must be managed in a particular way that takes the longevity and nature of the risk into account. The key question is this: how should we manage long-lived nuclear fuel waste, given that the radioactive elements in the fuel waste can, regrettably, damage our DNA, cause cancer, induce germ-line mutations (which might lead to deformed children), or even result in death?

Nuclear fuel waste clearly poses special ethical problems due to the nature and duration the harm involved. Basic familiarity with the scientific and technical aspects of the issue, however, is very important if we are to develop an applicable and effective ethical framework for managing long-lived nuclear waste (Blowers et al., 1991,

[1] CANDU is an acronym for "CANadian Deuterium Uranium." It is the only commercial reactor design currently used in Canada.

1-2). Just as a technical framework is unacceptable without ethical considerations, an ethical framework is likewise unacceptable if it fails to take into account the actual nature of the risks, harms, and limitations of viable nuclear fuel storage systems. With this in mind, the current chapter addresses the classification of fuel waste, the nature of radioactivity, and Canada's current proposal for the long-term management of our nuclear fuel waste. In the following chapter I will address the risks and biological effects of radiation exposure, as these are more appropriately investigated in the context of the justification of nuclear power and acceptable thresholds for radiation exposure.

3.1 Nuclear Waste

3.1.1 Classification of Nuclear Waste

Canada has been generating nuclear waste since the first radium mine began operating at Port Radium (in the North West Territories) in the early 1930s. High-level fuel waste was first produced in September 1945 with the startup of the experimental ZEEP reactor at Chalk River, Ontario, which was followed shortly afterwards in 1947 with the introduction of the NRX reactor. Commercial-scale reactors offering electricity to the public commenced with the Douglas Point reactor in 1966. Canada now has 22 commercial reactors, with 18 currently in operation at different sites (mostly in Ontario), each of which produces a significant quantity of nuclear waste.[2]

'Nuclear waste' refers primarily to all waste produced in the nuclear fuel chain, activities of which include: uranium mining, milling, refining and conversion, nuclear fuel fabrication, reactor operation, spent fuel, disposal, and reactor decommissioning (LL-

[2] By the end of 2004, Canadian nuclear fuel waste totalled $7,300m^3$, or approximately 40,000 metric tonnes; low-level radioactive waste totaled 2.3 million m^3; and Uranium mill tailings totalled 214 million tonnes (LLRWMO, 2004, i). The projected fuel waste inventory by 2033 is 15,000 m^3, more than double the current amount.

RWMO, 2004, p. 34).[3] Other sources include nuclear research, medical radioisotope production, and isotopes from irradiating food. Canada subdivides nuclear waste into four broad categories, with each level requiring different precautions and disposal methods (Blowers et al., 1991, 10):

(1.) *High level waste* (HLW): includes spent nuclear fuel and heat generating waste from reprocessing plants. This type contains the most radioactivity and is the most dangerous.

(2.) *Intermediate level waste* (ILW): includes fuel cladding, control rods and resins from cooling systems, in addition to other components closely related to energy production in the nuclear reactor process. Further categorization is sometimes made by separating ILW into *long-lived* (mostly transuranic wastes) and *short-lived* (mainly beta and gamma emitters); the division is based on half-lives more or less than 30 years (Blowers et al., 1991, 10).

(3.) *Low level waste* (LLW): by far the largest category in terms of tonnage, LLW includes lightly contaminated material such as clothing, mops, laboratory equipment, and decommissioning debris, etc; almost everything that workers use in-plant falls into this category, and must be (or at least *should* be) disposed of in specialized landfills separate from municipal dumps.

(4.) *Historic*: This includes waste "that was managed in the past in a manner no longer considered acceptable but for which the owner cannot be held responsible. The federal government has accepted responsibility for this waste," which now measures 1.7 million cubic metres (LLRWMO, 2004, 6).

These categories are used for basic classification and isolation requirements but they do not entirely reflect the degree of radioactivity of each component. For instance, *low-level* waste, according to the Canadian Nuclear Association, also includes, oddly enough, nuclear reactor buildings themselves. *Intermediate-level* waste includes ion-

[3]In some other countries, like Britain, France, U.S. and Japan, nuclear waste is (or has been) also produced via other processes, including uranium enrichment and reprocessing to recover uranium and plutonium.

exchange columns from cooling columns used in a nuclear power plant, and some other materials that are proximal to the core, such as the pressure tubes found in CANDU reactors. The pressure tubes, however, are enormously dangerous. As Resnikoff states: "Surprisingly, after 100 years, the pressure tubes will present a higher gamma radiation field than irradiated CANDU fuel itself and should therefore be managed in the same way as irradiated fuel" (Resnikoff, 1992). Should the pressure tubes be high-level or intermediate-level? I call attention to this problem to highlight the fact that how we should effectively classify the waste remains an open problem. (we shall see that issues like this are present throughout systematic reflection on the problem.) The present concern mandates that we put that issue aside for now and focus on the problem of managing *high-level* fuel waste. In Canada, "nuclear *fuel* waste" legally means "irradiated fuel bundles removed from a commercial or research nuclear fission reactor"[4] — spent fuel is always categorized as high-level waste. The used fuel, as we will see shortly, contains long-lived and highly radioactive isotopes like plutonium, uranium, and neptunium, which must be isolated from humans and the environment in a manner that requires more precautions than the other levels of nuclear waste.

3.1.2 Nuclear Waste Production

CANDU reactors use natural (unenriched) uranium for fuel, which contains a mixture of uranium-238 and about 0.7% of uranium-235; reactors that use enriched uranium have a 3% concentration of uranium-235.[5] When placed inside the reactor the uranium fuel undergoes fission to generate heat, which in turn boils water, and the subsequent steam is then used to turn a turbine; the end result is electricity that is used to power industry and our homes. The actual fission process inside the reactor occurs when a neutron bombards the fissile nucleus of uranium-235 — this process splits the atom into neutrons, creating different isotopes (fission products) and useful

[4]See the Canadian *Nuclear Fuel Waste Act*, section 2. <`http://laws.justice.gc.ca/PDF/Statute/N/N-27.7.pdf`>.

[5]Nuclear bombs use 80% enriched uranium-235, though a supercritical chain-reaction can be achieved with concentrations as low as 20%.

thermal energy.[6] A neutron released by the fission process has the potential to bombard another uranium-235 nucleus, causing yet another fission event. The set of such fission events is called a *chain reaction*, and it is said to be self-sustaining when each fission event causes (almost exactly) one other fission event, no more and no less. (An atomic bomb essentially involves ensuring that each fission instance produces *more than one* additional fission event; when this occurs, the chain reaction goes super-critical, releasing an enormous amount of energy — i.e., a nuclear explosion.) Curiously, of all the isotopes found in nature, only uranium-235 is a readily fissile isotope — that is, fission can be induced by neutrons of arbitrarily low energy; it is thus one of the most important isotopes for our use of nuclear energy (Wolfson, 1991).[7] Because the CANDU reactor design uses non-enriched uranium, it requires the use of a heavy water (deuterium) moderator, instead of light water (regular fresh water) to sustain a chain reaction.

It is the fission products of the nuclear fission reaction that pose the long-term health and environmental concerns. Wolfson (1991) provides a good summary of fission products:

> The products of nuclear fission have one thing in common: they are highly radioactive. ...When a heavy isotope undergoes fission, the fission products preserve the same ratio of neutrons to protons. But ...that leaves them unsta-

[6]The reverse process of fission is called *fusion*. Fusion occurs when two atoms fuse with other neutrons or isotopes and produce heavier elements. For example, two hydrogen atoms and two neutrons might combine to create helium (^4_2He) and thermal energy. This process occurs naturally in the sun (where the pressure and temperature are sufficient for the process) and in 'hydrogen bombs.' So far, however, we have not been able create sustained fusion reaction on earth (hydrogen bombs are definitely *not* controlled reactions), though an international effort (ITER) is currently underway to demonstrate the scientific and technical feasibility of constructing a fusion reactor. For more information on the progress of ITER, visit their website at <www.iter.org>. The project is, quite literally, an attempt to harness the same type of energy found in the sun. For those interested, the temperature needed to fuse the two deuterium isotopes (deuterons), the most promising isotope for this type of reaction, is 400,000,000 Kelvin; a balmy afternoon in Southern Ontario, by way of comparison, is only about 300 to 310 Kelvin.

[7]The other important fissile materials — plutonium-239 and uranium-233 — are 'artificial' in that they are the produced inside the reactor (and not found in nature) by irradiating uranium-238 and thorium-233 (Murray, 1993, 67). To be useful those isotopes must be extracted by reprocessing the used fuel.

ble. Some of those neutrons "boil off" almost instantaneously, giving the two or three neutrons produced in each fission event. But the remaining isotopes are still rich in neutrons. They decay, through a sequence of beta emissions, until they achieve stability. So the fission products are inherently radioactive. The half-lives of typical fission products range from less than a second to hundreds of years; since those times are much less than the roughly billion-year half-lives of uranium isotopes, the fission products are much more intensely radioactive than the original uranium (Wolfson, 1991, 110-111).

Let us briefly examine some of the basic physics referred to in the above quote. Atomic nuclei consist of nucleons — protons and neutrons — bound together by the strong nuclear force.[8] Hydrogen, the simplest nucleus, contains a single proton, but every other nucleus contains some combination thereof. For instance, Deuterium (also known as 'heavy water') contains a proton and a neutron, while Tritium contains a proton and two neutrons. Atoms with the same number of protons but a different number of neutrons are known as *isotopes*. The next element, Helium, has two isotopes, one with 3 protons and another important one with 4 protons. Not all nuclei, however, are intrinsically stable. Those that are not stable must ultimately 'come apart,' a process known as *radioactive decay*. (Radioisotopes are simply unstable atoms.) The familiar term for an atom's rate of radioactive decay is its *half-life*. The half-life ($t_{1/2}$) of an element is the time it takes an element to decay to one-half its original mass.[9] For example, the $t_{1/2}$ for radioiodine (^{129}I) is 8.09 days, so after that time 1 gram will have 'decayed' (into beta-rays and xenon for this element) and only 0.5 gram will remain of the original amount.

When an atom undergoes radioactive decay it emits either an alpha particle, beta particle, or gamma ray (or combination thereof), in addition to heat. These emissions are what can cause harm by damaging our cells and DNA, leading to an increased risk of contracting cancers like leukemia (among other forms) or an increased risk of birth

[8]The radius of the atomic nucleus is only 1/100,000th that of the entire atom, which also consists of negatively charged electrons.

[9]Mathematically, $t_{1/2} = \frac{ln(2)}{\lambda}$, where ln(2) is the natural logarithm of 2 (approx 0.693) and λ is the decay constant, a positive constant describing the exponential rate of decay.

defects.

In the process of *alpha decay* (α) the atom ejects a helium isotope, historically referred to as an alpha particle (^4_2H, or Helium-4); that is, it sheds two protons and two neutrons. The atomic number of the parent atom subsequently drops by 2, and the mass number by 4. For example, when uranium-238 ($^{238}_{92}U$) undergoes alpha decay it emits an alpha particle and heat, leaving only the thorium-234 ($^{234}_{90}Th$) isotope (Wolfson, 1991) — the original uranium-238 atom has been, in other words, transmuted into a different atom.

Of the three main forms of harmful radiation, alpha particles are the most densely ionizing but least penetrating form. A single sheet of paper, or even our own skin, is thick enough to stop an alpha particle.[10] Although there is little danger if the radiation remains outside of our bodies, an alpha-emitting isotope can damage our cells and our DNA if ingested or inhaled. Tritium (a heavy form of hydrogen) is an alpha-emitter, and a common element in Canada's nuclear programme; most long-lived transuranic elements, like Plutonium-240, are also alpha emitters (LWVEF, 1985, 18). For this reason the danger of long-lived isotopes comes from ingestion or inhalation, and not from direct external exposure (unless the amount of exposure is significant).[11] Ruth Fawcett explains this process clearly:

> Most of the radioactive elements in the used fuel decay rapidly to stable elements. One hour after removal from the reactor, the used fuel bundles have lost over 60% of their radioactivity; however, the remaining fission products are still highly penetrating. One year later, a person would still receive a lethal dose of radiation from the used fuel in about ten minutes. After 500 years, the penetrating radiation is no longer a threat but the longer-lived elements still give off radiation that would prove dangerous if ingested. It is for this reason that any disposal system must ensure that these fission products do not contaminate the environment.[12]

[10] This is a common belief, but some recent research has called this assumption into doubt.

[11] <http://www.cna.ca/english/pdf/NuclearFacts/13-NuclearFacts-whataboutradiation.pdf>

[12] See Fawcett, Ruth. (1993). "High-Level Radioactive Waste in Canada." Science and Technology

Alpha-emitters pose the major long-term threat, but beta and gamma emissions pose the most significant short-term danger. When an unstable nuclei has too many neutrons it would like to either shed neutrons or gain protons. In *beta decay* it does both: a neutron breaks into a proton and an electron. The proton remains within the nucleus, but the high-velocity electron (β^-) is ejected. The remaining atom therefore has one less neutron and one more proton, so its atomic number increases by 1; the total number of nucleons remains the same and so its mass number is unchanged. In other words, "beta particles are electrons that come from transformation of a neutron in the nucleus of an atom to a proton. They can travel up to about five metres in air and one centimetre in tissue."[13]

Sometimes there is excess energy left over after an α or β decay. When the nuclei subsequently drop from this excited state to a more stable state, a *gamma ray* (γ) is emitted. Gamma rays are the same type of energy as visible light but 1 million times more energetic. Whereas visible light is harmless to us, the energy in gamma rays can destroy our cells and damage our DNA even if the source is far away.

3.2 Adaptive Phased Management (APM)

> The price that we demand of society for this magical energy source is both a vigilance and a longevity of our social institutions that we are quite unaccustomed to
> (Weinberg, 1972, 33).

In 1977 the federal government established a commission chaired by Kenneth Hare to examine the issue of safely disposing of nuclear fuel waste. Hare reported that "Canada urgently need[ed] a plan for the management and disposal of nuclear wastes" (Steed, 2007, 175). The following year the Government of Canada and the Province

division, Government of Canada. Report: BP-338.
<http://dsp-psd.tpsgc.gc.ca/Collection-R/LoPBdP/BP/bp338-e.htm>.

[13] <http://www.cna.ca/english/pdf/NuclearFacts/13-NuclearFacts-whataboutradiation.pdf>.

of Ontario established the Canadian Nuclear Fuel Waste Management Program to explore and develop safe disposal methods of nuclear waste. The crown agency Atomic Energy of Canada Limited (AECL) was given the responsibility of researching the feasibility of "disposal in a deep underground repository in intrusive igneous rock of the Canadian Shield,"[14] a method generically known in the industry as Deep Geological Disposal (or DGD). Toward this end the AECL constructed an Underground Research Laboratory (URL) near the community of Lac du Bonnet in Whiteshell Provincial Park, Manitoba. The research centre extended to depths of 450 meters through granitic pluton known as Lac du Bonnet Batholith, a hard, intrusive igneous rock typical of the Canadian Shield; the rock dates back to the Precambrian Era — 4.5 billion to 540 million years ago, and is some of the most tectonically inactive rock on the planet.

In 1989 an Environmental Assessment Panel (the Seaborn Panel) was formed to examine the AECL's results and query the general public about nuclear waste disposal. Public hearings were held for 12-months during 1996 and 1997, and the Seaborn Report was submitted in 1998. It found the deep geological disposal concept technically sound, despite 93 potentially serious technical difficulties. The Panel concluded, however, that "the AECL disposal concept has not been demonstrated to have the level of acceptability required to be selected as Canada's approach for managing nuclear fuel wastes," due almost entirely to a lack of "public acceptability."[15] Some of the concerns expressed included a need to monitor the waste, transparent financial accountability, assurances that future generations won't be saddled with financing the storage facilities (an equity and fairness condition), and provide "the flexibility for future generations to make their own decisions." In other words, though technically acceptable, proposed methods of disposal had so far been ethically (broadly interpreted) unacceptable. Ethical principles or guidelines mentioned as significant in the report include: safety from harm, responsibility, adaptability, stewardship, accountability and transparency, knowledge (inform citizens), inclusion (broad range of perspectives), fairness, and environmental integrity.

[14] <http://www.aecl.ca/index.asp?menuid=500&miid=544&layid=3&csid=301>.
[15] <http://www.ceaa-acee.gc.ca/010/0001/0001/0012/0001/6_e.htm>.

Given public concerns, the Government of Canada responded to the Seaborn Panel by passing the Nuclear Fuel Waste Act (NFWA) in November 15th 2002, an Act which requires the investigation of a workable solution by comparing the options. This Act established the Nuclear Waste Management Organization (<www.nwmo.ca>) to undertake research of viable means of disposing of Canada's high-level nuclear waste by evaluating three technical methods: deep geological disposal in the Canadian Shield, centralized storage either above or below ground, and storage at nuclear reactor sites. The Seaborn Panel also strongly recommended that the whichever organization became responsible for the nuclear fuel waste should be independent from the nuclear industry. Unfortunately, the government deliberately ignored this recommendation when it established the *nwmo*.

The results of the NWMO's study, as mentioned in the previous chapter, were presented in November 2005. They recommend deep geological disposal under an approach they call "Adaptive Phase Management" (APM).

3.2.1 Details of APM

In a general characterization, Adaptive Phased Management

> is a technical method and a management system. The method is implemented in stages with the end goal of centralizing all of Canada's used nuclear fuel in one location, and isolating and containing it deep underground in a suitable rock formation. The management system is phased and adaptive, with explicit decision-points to incorporate new social learning and technological innovation as it is implemented. At each stage options, including a contingency for temporary shallow underground storage, can be evaluated and the plan modified before proceeding. A future society will decide whether and when there is sufficient confidence in the safety of the approach to seal and backfill the repository.[16]

[16] <http://www.nwmo.ca/Default.aspx?DN=1498,50,19,1,Documents>.

The NWMO considered several options for waste storage, such as deep geological disposal, lake-bed disposal, permanent shallow storage on-site at the generating reactor, and a version of deep geological disposal with retrievability and monitoring (Adaptive Phased Management). Parliament and the nuclear industry have chosen the last option, claiming it is the "strongest possible foundation for managing the risks and uncertainties that are inherent in the very long time frames over which used nuclear fuel must be managed with care" (Nash & Dowdeswell, 2005a).[17] Adaptive Phased Management is a long-term storage option, the key features of which are "ultimate centralized containment and isolation of used nuclear fuel 600m below the surface, phased and adaptive decision making, optional shallow storage at the site prior to the placement in the repository, continuous monitoring, option for retrievability, and public consultation and engagement" (Nash & Dowdeswell, 2005a, 23). The first phase is primarily regulatory — environmental assessments, site selection, and licensing; this phase is expected to take 30 years to complete. Phase 2 will take another 30 years, and this involves making the decision to go ahead with the plan and begin construction. Phase 3 is the stage where used fuel will be placed inside the underground facility; this phase will occur approximately 60 years after the commencement of phase 1. (See figure 3.1.) Note that no waste will be permanently placed in the facility until at least 60 to 70 years after the approval of a site location, a full 120 years after the start of Canada's foray into nuclear power.

The full cost of Adaptive Phased Management "is conservatively estimated to be about $24 billion (2002 dollars)" (Nash & Dowdeswell, 2005a). The entire process rests on the assumption that the financial resources for each phase will be available, and that there will be no significant public opposition to the plan. The NWMO does not have a back-up plan in case either of these conditions is not met. Note that the time frame for emplacing the first used fuel in the repository is longer than Canada's nuclear history so far. It may not be prudent to expect that social circumstances

[17]But burying the waste has a further consequence, namely that it will be placed 'out-of-sight, out-of-mind,' and this may lead detract from our awareness of the remaining issues. According to Prof. Timmerman, "The possibility of failed surface management is a constant theme of engineers and managers with AECL; this goes against the proposal (from some anti-deep disposal activists) that the waste should be kept on the surface to remind us of what is happening" (Personal communication).

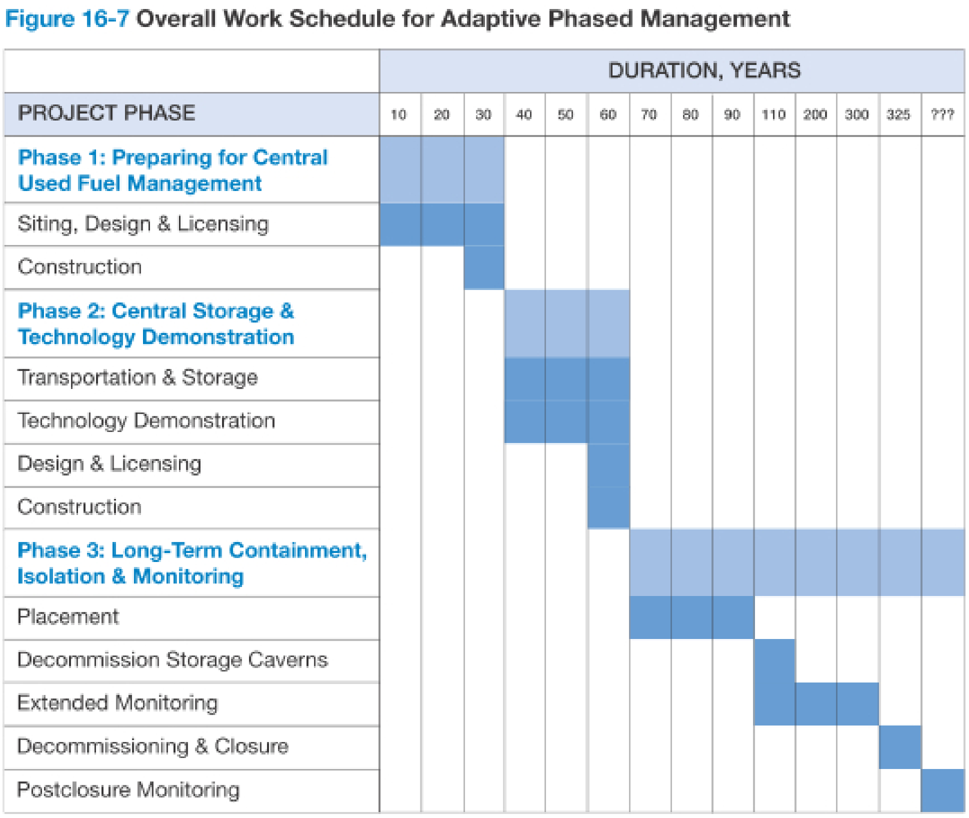

Figure 3.1: Timeline for Adaptive Phased Management (Nash and Dowdeswell, 2005).

will remain favourable to nuclear power for another 60 years and, if circumstances do change, then future people will be forced to deal with our problem with no recompense from the present generation (and the generators of the initial waste).

3.2.2 Advantages and Disadvantages of APM

Adaptive Phase Management offers several attractive advantages over the alternative options; see figure 3.2 for the original description of the risks and benefits associated with this approach. According to the NWMO, Adaptive Phased Management offers, in part, the following benefits:

(1.) This approach "places the majority of responsibility on the current generation for ensuring that the long-term management facility is in place. It supports intergenerational fairness in limiting the burden on future generations to take further actions in managing the fuel" (Nash & Dowdeswell, 2005a).

(2.) It will provide significant short-term economic boom for the host community.

(3.) The facility will limit exposure to hazards and is "designed to be passively safe which should limit overall risks and uncertainty."

(4.) Monitoring of the waste in case of leaks or disruption so that we can repair the damage early.

(5.) Retrievability in the case of an accident or leak.

(6.) Retrievability in case of a desire by future generations to reprocess the waste to use as fuel in more nuclear reactors.

Finally, it claims that

> As a blend of a flexible centralized storage facility over the next 300 years, coincident with an extended period of proof of concept activities, and final placement of used nuclear fuel in a deep repository, this approach is judged to provide the fairest distribution of benefits and risks within this generation and across generations.

The NWMO also recognizes a number of potential drawbacks to its approach.

(1) In the longer term, it provides little flexibility for future generations to influence the management of used nuclear fuel or to make fundamental changes without incurring considerable additional costs.

(2) There is some uncertainty associated with how the system will perform over the long term. In the unlikely event of a breach of containment, it may be difficult for a future generation to detect the breach in a timely way and take corrective action.

Table 8-2 (cont'd) Fairness

	BENEFITS	RISKS & UNCERTAINTY
Option 4: Adaptive Phased Management	Places the majority of responsibility on the current generation for ensuring that a long-term management facility is in place. Supports inter-generational fairness in limiting the burden on future generations to take further actions in managing the fuel. Responds to the sentiment of Canadian society, that the generations of citizens benefiting from nuclear power and creating the associated wastes have an obligation to provide a lasting means for managing that waste while at the same time preserving options for future generations to make decisions that they believe are in their own best interests. It calls for the construction of permanent facilities early in the implementation process in order to ensure that this generation has provided for viable long-term management facilities to reduce the burden on future generations. It calls for an extended period of flexibility in decision making in moving from current reactor site storage to eventual placement in a centralized deep repository and the potential sealing of this repository. This will leave room for future generations to influence the final stages of implementation, particularly over the period in which it is reasonable to expect that societal institutions will remain strong. Provides for an extended validation and optimization program, to enhance ultimate performance of the facility. Through proactive contingency planning, it ensures there are safe and secure storage facilities available for management of the used fuel at each point in the process. Implementation is phased, allowing for time to learn and benefit from new science and emerging findings on technology and to continue to gauge the risk and uncertainty in light of new knowledge associated with moving through the phases. This includes leaving the decision to a future society regarding the best time for closing and sealing the deep repository.	This approach attempts to balance the uncertainties and potential implications to fairness associated with Option 1 and with Option 3. It attempts to optimize flexibility in the near term, and ensure there is an option in place to contain and isolate the waste in the very long term, which does not rely upon human intervention. However, in so doing, it carries the risks of flexibility in the near-term period, although these risks are expected to be less than in the storage approaches because the period of risk is timed to coincide with the period in which it is reasonable to believe we are in the best position to actively manage this risk. In the very long term, it also carries the risks associated with the repository system, although these risks are expected to be less as a result of the planned extended period of technology investigation, testing and confirmation and the adaptive staging embodied in this approach. Depending upon the community selected, it could be in a region not having directly benefited from the production of nuclear energy. The flexibility of geologic media, some of which can be found closer to existing reactor sites, allows greater flexibility in siting and potentially a fairer distribution of benefits, costs and risks compared with Option 1. Transportation of the used nuclear fuel will involve more communities in the risk associated with the implementation of the approach. However, it is expected that this risk will be small. The fundamental importance of collaborative decision-making at multiple points in the implementation, which is embodied in this approach, is also expected to ensure that fairness issues associated with siting, as these are understood by those most directly affected, will be identified and explicitly addressed before any site decision is made.

Figure 3.2: The original description of the risks and benefits of Adaptive Phased Management (Nash & Dowdeswell, 2005).

(3) Although it offers a significant economic boom to a host region and province, this is expected to be followed by a rapid decline (bust) after construction of the deep repository and placement of fuel in it.

(4) Transportation of the used nuclear fuel will involve more communities in the risk associated with the implementation of the approach.

Judging by the above risks and benefits, and referencing the descriptions provided by the NWMO in figure 3.2, it is hard to proceed without (a) some quantitative results by which to compare the available options, and (b) some consistency in the use of the term 'risk.' For instance, with respect to the possible transportation accidents in number 4, the NWMO claims that "overall, radiation exposures for normal and off-normal transportation activities are considered very small." And for intrusion into the facility, the NWMO states that: "The probability of off-normal scenarios during the near term is very low. As well, with a negligible likelihood of human intrusion after the facility is closed, institutional controls would have to fail during the operational period for there to be even a risk of human intrusion and the resulting unacceptable risk to the public" (Nash & Dowdeswell, 2005a). To say that the 'risk is very small' or 'very low' indicates that a risk assessment has been performed and the possible risks quantified for comparison among the various disposal options. Unfortunately, the final study report does not offer further guidance on the matter. Nevertheless, it is important to clarify the concept of risk and risk assessment in this context.

3.3 Risk Assessment

We often use the term 'risk' in a variety of ways during everyday discussions. For example, you could be at risk of contracting the H1N1 virus, engaged in a risky business venture, or risking your life by crossing a busy highway. In the present case the term 'risk' is used in a specific way, though it is not always used clearly and consistently. *Risk*, according to William Leiss, is the "predicted or expected chance that a set of circumstances over some time frame will produce some harm that matters" (Leiss, 2003).[18] Estimating risk involves characterizing the relevant elements in our answers to the following three questions (Kaplan & Garrick, 1981, 13):

> What can go wrong?
> How likely is the event?
> What are the consequences?

To answer these questions — and perform a risk assessment — a risk analyzer establishes a triplet of elements: a description of each possible accident *scenarios*, the *probability* or likelihood of occurrence for each scenario, and the predicted *consequence* or measure of damage for each scenario (Kaplan & Garrick, 1981). Thus, for each of the possible nuclear waste disposal options — such as sending it into space, burying it in the ocean, entombing it in ice-sheets, entombing it deep in the earth's crust, and so on — one calculates the likelihood of various accidents scenarios occurring for each option, and the possible health and environmental damage resulting from each accident. Whichever options yields the lowest chance of an accident occurring, and has a reasonably low consequence in case of failure, is deemed to be least risky option.

A good risk assessment will calculate the values for a robust set of potential hazards which might occur in each scenario; these hazards can be broadly categorized into natural, technical, and social hazards. Natural hazards include events such as earthquakes, floods, forest fires, disease outbreaks, and ice and snow storms; climate change might also be classified as a natural hazard because it exacerbates the frequency and magnitude of natural events. Technical hazards include electrical grid failure, nuclear reactor events (and release of radioactivity), urban air pollution, faulty materials for the waste containment structures, and so on. Social hazards, on the other hand, include a range of events such as terrorism, political instability, ethnic hostility and violence, widespread crime, and poverty and injustice (Leiss, 2005). We can achieve

[18] I want especially to thank Professors Mathieu Doucet and Patricia for their helpful comments on this section conveyed to me on an earlier draft of this document.

good risk management by anticipating several possible hazards and the potential extent of damage and institute procedures to either prevent damage from occurring or implement disaster preparedness procedures in case rare but dangerous events do occur. As William Leiss states in a recent commissioned report for the NWMO, "The fundamental idea of good risk management is to anticipate and prepare for the potential damages to persons and property associated with major hazards; this is the essence of a precautionary approach" (Leiss, 2005). The NWMO will do its best to minimize risk by isolating the waste in stable rock formations in a location distant from large urban areas where a large release of radioactive particles and material would do significantly more damage. The condition of isolating the waste and instituting multiple layers of defence in case of an accident is accounted for by the NWMO's DEFENCE-IN-DEPTH conditions, of which I will have more to say in the next chapter.

Though a good risk assessment will calculate the values for a robust set of potential scenarios, there will always be some possible accidents which we do not foresee (or cannot foresee due to lack of available information), and hence some degree of uncertainty is inherent in all risk assessments. The essential element of risk, after all, is uncertainty. Kaplan and Garrick cite a critic of the now discredited Rasmussen report — a widely cited report which examined the likelihood of a nuclear reactor meltdown in the U.S. — makes the problem of inherent uncertainty explicit:

> A risk analysis is essentially a listing of scenarios. In reality, the list is infinite. Your analysis, and any analysis, is perforce finite, hence incomplete. Therefore no matter how thoroughly you have done your work, I am not going to be trust your results. I'm not worried about the scenarios you have identified, but about those you haven't thought of. Thus I am never going to be satisfied (Kaplan & Garrick, 1981, 14-15).

To say that one would never be satisfied is disingenuous, as it requires that one neglect the fact that some degree of risk is inherent in all of our activities — we might say it's an unavoidable aspect of our mortal lives. Rather, the important questions to ask are: How much risk is satisfactory (or acceptable) for the benefit of electricity provided by nuclear power? And an important related question: Is there a threshold of risk beyond which the activity would be unacceptable, regardless of the financial or electrical benefits? Answering the first question assumes that the risk calculations for each scenario have been assessed and quantified. This data is not included the NWMO final study report, so it is not apparent how one is expected to make a decision on the Adaptive Phased Management approach beyond reliance on the NWMO's *assertion* that APM is *less risky* than, say, above-ground shallow storage or on-site storage. This is quite surprising because in the risk assessment section, the NWMO quantifies the projected financial costs for each option but doesn't quantify its measure of risk or its assessment of the riskiness of each option in the Final Study document. Without such quantification we literally cannot make a determination one way or the other about the risk involved for each option based on the likelihood of particular accidents in the various scenarios considered.

The second question about satisficing — namely whether or not there is an absolute threshold of acceptable risk — is also unanswerable based on the information provided.[19] Nowhere in the final study document are we presented with data about the projected health impact from *exposure* to radiation for each option over time. How many cancers are expected to arise from Adaptive Phased Management? How many cancers are expected from storage solutions on-site at each reactor? What is the likelihood of a nuclear fuel waste transport truck failing and spilling its radioactive contents on the side of the road? How many such accidents are expected over time, and what are the environmental and human health effects from such accidents? The risk is evidently *not zero*, otherwise there would not be any risk whatsoever. (Risk, after all, requires both uncertainty *and* some potential for damage from the hazard.)

[19] The term "satisficing" was coined by the economist Herbert Simon in 1957 (Simon, 1982). His reasonable claim is that we are limited agents (with limited resources, money, and time), but we still need to make decisions based on the information and time available. So for decisions under some constraints, rational agents may opt to satisfy their preferences rather than attempt to optimize their preferences. That is, we may choose a solution that offers an acceptable level of risk because it can be implemented in a reasonable amount of time and for a reasonable price, rather than attempt to search for or implement the extremely expensive alternative solution which would maximize safety (or the solution which genuinely minimizes risk). There will, of course, always be trade-offs for any solution, and as rational agents we are trying to maximize our preferences, but may have to settle for merely satisfying (rather than optimizing) our preferences; moreover, it is rational to do that.

But since there is *some* risk involved, a good risk assessment will quantify, even if only by approximation, the uncertainty and likelihood of possible radiological damage for each scenario. Unfortunately, this information is not provided, and hence we cannot make an informed decision about where to establish a threshold of risk to our health, let alone determine whether or not we would be satisfied with one option over another, at least from a risk assessment perspective. This is doubly worrisome because the NWMO explicitly mentions this concern in its principle Q9: "Special ethical issues arise with respect to risk assessment in the nuclear industry. For example, might some scenarios be so horrendous that even a slight risk of their occurrence would be morally unacceptable or unacceptable by Canadians?" (Nash & Dowdeswell, 2005a). But again, without quantification of the 'slight risk' and the possible damage for such predicted scenarios, we cannot offer an informed response; and in this type of situation, where the possible damage from radioactive release is substantive, the rational position dictates that we err deep on the side of caution.

3.4 Future Waste

In its five-year plan, the NWMO makes a telling remark: "We must also be ready to demonstrate the adaptability of APM to the potential implications of changes in nuclear energy policy, such as the management of used fuel from new nuclear generation plants" (NWMO, 2008b), despite the fact that its plan was evaluated explicitly for existing waste only. However, Canada is on-track at the moment to build new nuclear reactors, and that waste will also have to go somewhere. Unfortunately there has been no significant debate, or resolution, about the ethical and social acceptability of generating nuclear fuel waste from new nuclear reactors, and the concern is doubly worrisome in that the "scenario of new used nuclear fuel was not considered by the Roundtable [on Ethics]" when they deliberated on what to do with the waste that we've already generated. Given that the APM approach, as developed by the NWMO, only considers existing waste and presently commissioned waste (through the operation of existing reactors), we do *not* have a solution for the storage of used nuclear fuel generated by any newly-developed reactors.

There is also an important question about the type of used fuel that will be placed in the storage facility. At the present time Canada uses a "once-through" fuel chain. That is, uranium is mined, milled, processed into fuel pellets and bundles, placed in the reactor for 18 months, and then removed for cooling and storage. Another option, which future reactors might make use of, is to "reprocess" the used fuel. Reprocessing uses chemical and physical means to extract fissile material (like plutonium, uranium and thorium) from spent nuclear fuel, which can then be placed back into a reactor. Despite the fact that Canada does not currently have an energy policy that allows for the use of reprocessed fuel, the NWMO makes it clear that reprocessing is a possible option for meeting Canada's future nuclear fuel needs. As they say, it is recognized that nuclear fuel cycles other than "once-through" fuel cycles like CANDU are "aimed at the optimum use of uranium and/or plutonium and could at some point be implemented in Canada and some of these fuel cycles could involve reprocessing" (Nash & Dowdeswell, 2005a, 287).[20]

There are number of reasons why we don't currently reprocess nuclear fuel. According to Greenpeace, reprocessed fuel is "expensive and it does little to help waste disposal. Reprocessing merely splits the spent fuel into different parts and does not reduce the amount of radioactivity to be dealt with or the heat load. Indeed, reprocessing creates a large amount of low- and intermediate-level waste because all the equipment and material used in reprocessing becomes radioactive waste" (Greenpeace International, 2007). In Canada, it is estimated that the reprocessing of CANDU fuel will cost $1,500 per kg of uranium, whereas the July 2005 cost of mined uranium (U3O8) is $80 per kg (Nash & Dowdeswell, 2005a, 387). Thus, to reprocess 3.7 million bundles of used CANDU fuel would cost about $107 billion (in 2005 dollars). Though this is not economically feasible today, the NWMO urges that we keep the waste retrievable and give future generations the option of access in case economic conditions change

[20]Obviously this process is not a 'cycle' in that the end product is not reintegrated into process; however, calling the process a 'fuel-cycle' rather than a 'fuel-chain' (or something like that) is the vernacular in the Industry.

and reprocessing becomes viable.

Even if the economic feasibility of reprocessing in Canada becomes reality, "there would still be radioactive wastes to manage and reprocessing would increase the types of wastes and the risks of spreading technology that could be used for production of nuclear weapons" (Nash & Dowdeswell, 2005a). Moreover, reprocessing "inevitably produce[s] residual radioactive wastes that could be more difficult to manage than used nuclear fuel in its un-reprocessed form" (ibid.). In other words, according to the NWMO, there will be more radioactive waste — creating even more problems for waste management — and the added risk of nuclear weapons proliferation. This is a dangerous path to embark upon, and one that should not be done surreptitiously.

We need to take the possibility of using reprocessed fuel seriously because the "once-through" nuclear fuel-chains are thought not be 'sustainable.' Uranium is quite finite, and the amount of economically minable uranium is projected to last only for the next 80 years at the current rate of usage, and even less if countries continue to build new nuclear reactors (van Leeuwen & Smith, 2006). Once we have depleted the known uranium-ore deposits, we will be forced to reprocess our nuclear fuel. We are probably therefore going to pass the world on to future generations in such a state that they will be left without economically viable uranium-ores, and will be forced, should they desire to continue to use nuclear power, to reprocess our waste, with all of the concomitant dangers and expense listed above.

3.5 Summary

Canada has a significant quantity of highly radioactive nuclear waste that must be isolated from human and environmental contact for eons. Several options for storing the waste have been considered, both nationally and internationally, including sending the waste into space, burying it in an ocean or the Great Lakes, emplacing it in salt-beds, keeping it on-site at the generating reactors, or permanently burying the nuclear waste deep within the rock of the Canadian Shield. After evaluating some options suitable for Canadians, the Nuclear Waste Management Organization (NWMO) recommends that we bury the waste in the Canadian Shield, with the provisos that the waste is both monitored and retrievable. It calls this approach Adaptive Phased Management (APM), and believes that provides "the fairest distribution of benefits and risks within this generation and across generations." The entire process is expected to take 100 years, and cost at least $24 billion.

Deep questions and concerns were raised about the comprehensiveness, accuracy, and clarity of the cost-benefit approach used by the NWMO to justify APM. There remain yet more of these concerns and criticisms, and they form the focus of the following chapters.

Chapter 4

Justifying Nuclear Power

> Q5: Does NWMO provide a **justification** for its decisions and recommendations? In particular, when a balance is struck among a number of competing considerations, is a justification given for the balance selected?

Using nuclear power to satisfy our energy demand is, according to the nuclear industry, fundamentally a matter of weighing the benefits of nuclear power (economic, medical, and social) against the costs of containing the resultant radiation from exposure to humans (and the environment), as well as the costs of cleaning up or compensating for damage incurred as the result of a nuclear power accident. If the benefits (positive effects) are greater than the costs (negative effects), then nuclear power is, presumably, *acceptable*; and unacceptable otherwise. All that remains is determining what, exactly, are the actual benefits afforded by using nuclear power, and delineating the exact costs and *risks* of harm.

The International Atomic Energy Agency (IAEA)[1] clearly states that "the acceptance by society of risks associated with radiation is conditional on the benefits to be gained

[1]The International Atomic Energy Agency is an independent international organization that reports annually to the United Nations. Its mission is to encourage the development of atomic energy for peaceful purposes, assist member states with procuring materials for the practical application of atomic energy, foster the exchange of scientific and technical information, and to "establish and administer safeguards designed to ensure that special fissionable and other materials, services,

from the use made of radiation," with the proviso that "the risks must be restricted and protected against by the application of radiation safety standards (IAEA, 1996a, 1). All that needs to be done is to demarcate and quantify the benefits and potential harms, and evaluate them relative to the appropriate safety standards; this is a standard cost-benefit approach to justification. And, like any good business practise, if "the risks outweigh the benefits, the operation should, of course, be rejected" (Cohen, 1972, 55). The principles underlying this approach are explicitly stated by the IAEA:[2]

> **(A): Justification of Practise.** No practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes.
>
> **(B): Optimization of Protection.** ... the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received should all be kept as low as reasonably achievable, economic and social factors being taken into account.
>
> **(C): Individual Dose Limits.** The exposure of individuals ... should be subject to dose limits ... aimed at ensuring that no individual is exposed to radiation risks that are judged to be unacceptable.[3]

The terms 'practice' and 'optimization' have very specific meanings in this context. By 'practice' is meant any human activity that increases the overall exposure to radiation, and this of course includes all activities related to nuclear power. 'Optimization' is the process of "deciding on the method, scale and duration of the action so as to obtain the maximum net benefits" (ICRP, p. 76). The net benefit is the difference

equipment, facilities, and information made available by the Agency or at its request or under its supervision or control are not used in such a way as to further any military purpose." See <`http://iaea.org`> for more information.

[2]Both the The International Commission on Radiological Protection (ICRP) and International Atomic Energy Agency (IAEA) articulate the same principles.

[3]See ICRP's "Radiological Protection" report summary, 1990; and the IAEA's "Basic Safety Standards for Radiological Protection" (IAEA, 1996a). The question of who 'judges' the risk to be unacceptable is left undefined. It is thus quite possible that an 'unacceptable risk' from the perspective of a nuclear power operator will not match an 'unacceptable risk' from the perspective of a civilian.

between the positive utility associated with nuclear power (jobs, electricity, clean environment) and the costs incurred — risk of harm from radiation, long-term isolation requirements, and a cost allowance for social anxiety. *Nuclear power is acceptable, according to the* IAEA*, if it meets conditions (A)-(C).* We must therefore examine whether or not these conditions (or principles) are satisfied.

Some points of clarification are in order before we proceed. A cost-benefit analysis like the one provided by the nuclear industry involves two crucial considerations: (i) weighing the benefits of nuclear power against the long-term cost of radiological protection, versus (ii) weighing the advantages and disadvantages of nuclear power relative to another source of energy, such as coal-fired plants, hydro, solar, or wind power; in these cases the comparison is constrained by such items as green-house gas emissions, affordability, and reliability. I hold the position that we need an ethical framework for nuclear waste management which is independent from considerations of affordability, efficiency, and reliability relative to alternative sources. If we do not have an ethical framework for nuclear power, and nuclear fuel waste management in particular, no amount of comparative analysis with other sources of energy will make it an ethical venture.

4.1 Justification of Practice

As with any cost-benefit approach, the first step is enumerating and evaluating the benefits and costs that are either received or incurred by the given action. What, then, are the benefits? Duncan Hawthorne, CEO of Bruce Nuclear Power, cites several benefits: (a) it is a secure source of clean electricity for years to come; (b) nuclear power provides a safe and reliable supply of baseload power at stable prices; (c) nuclear power is a zero emitter and perhaps the biggest single contributor in the battle against the global warming effects of burning fossil fuels; and (d) nuclear power ensures the security of our domestic electricity supply[4]; in addition, (e) the industry creates between 20,000 to 30,000 jobs. These are obviously desirable characteristics for an energy source.

These claims are further reiterated by the Canadian Nuclear Association, a nuclear industry organization with the mandate to 'promote the development and growth of nuclear technologies for peaceful purposes.' They have repeatedly stated in several long-running television and print advertisements that nuclear energy is "*Clean, Reliable, and Affordable.*"[5] The 'clean' aspect refers to the idea that nuclear power does not release pollutants, including gases, that contribute to global-warming. According to their website and literature:

> Nuclear energy is clean. It's North America's largest source of emission-free energy, which means *it emits no pollutants into the environment.* This keeps the air clean, prevents acid rain, and preserves the earth's climate and avoids ground-level ozone formation. And nuclear waste is managed in a safe, environmentally responsible way (<www.CNA.ca>; emphasis mine.)[6]

Taken together these constitute the dominant public justification of nuclear power in Canada. However, any *good* justification must also be *true*, or at least reasonably accurate, in order to be acceptable. Let us examine one of those claims here. The claim that nuclear power is "clean" and "releases no pollutants" is strictly false and, perhaps, even disingenuous. Every nuclear reactor regularly releases pollutants into the environment during normal operations. The International Atomic Energy Agency (IAEA) itself admits that it is "virtually certain that some radiation exposures will result from the normal performance of practices and that their magnitudes will be predictable, albeit with some degree of uncertainty: such expected exposures are referred to in the IAEA's Basic Safety Standard manuals as 'normal exposures."' (IAEA,

[4]See Duncan Hawthorne's speech "Nuclear Power: Friend of Foe?" <`http://www.cna.ca/english/pdf/Speeches/03April25AMPCO.pdf`>.

[5]See <`http://www.cna.ca`>.

[6]<`http://www.cna.ca/english/pdf/NuclearFacts/02-NuclearFacts-environment.pdf`>

1996a).[7] These 'normal exposures' can come from a variety of sources during regular operation of a reactor, in either gaseous, liquid or solid radioactive waste forms (IAEA, 1996b); I will have much more to say on this matter shortly.

Aside from radioactive pollutants, the claim that 'nuclear power is clean' is further undermined by the fact that using nuclear power leads to millions of tonnes of carbon-dioxide (CO_2) and other green-house-gas emissions if we consider the entire fuel chain. For example, in constructing a reactor "millions of tonnes of steel (1.6 million) and concrete (14 million) need to be manufactured and delivered to the chosen site." Furthermore, in addition to the hundreds of trucks (and their gas) required to transport this material, "for every tonne of Portland cement manufactured, a tonne of CO_2 is released into the atmosphere. The same goes for steel. Core reactor parts will most likely be manufactured in Japan and shipped over" (Hughes, 2007, 43). But reactors also need fuel. Assuming 0.01 to 0.02 percent concentration (100-200g of uranium per tonne of rock), about "98,000 tonnes of rock has to be mined and milled to give up one tonne of uranium" (Hughes, 2007). Mining and milling are, of course, energy intensive activities which require tonnes of CO_2, in addition to vast quantities of sulphuric acid to leach the uranium from the ore to produce the "yellowcake" that will be processed into usable fuel. These are only a part of the full processing necessary to effectively operate a nuclear power reactor. According to a comprehensive study by J.W. Storm van Leeuwen (van Leeuwen & Smith, 2006), nuclear reactors release between 100 — 140 grams of CO_2 per kilowatt hour (g/kWh) if we include the full fuel chain, and assume relatively high-grade uranium ore. A typical reactor today, with the carbon costs of the entire fuel chain incorporated, will require at least 20 years to repay its carbon incurred by the processes necessary to build, operate, and decommission the reactor. Thus, despite the Canadian Nuclear Association's claim above, nuclear power operations *do release* significant quantities of 'green-house-gases,' in addition to literally tonnes of high-level radioactive waste that must be safely stored (if at

[7] If the exposures are unexpected but possible they are called 'potential exposures.' Potential exposures "can become actual exposures if the unexpected situation does occur; for example as a consequence of equipment failure, design or operating errors, or unforeseen changes in environmental conditions, e.g. at a disposal site for radioactive waste" (IAEA, 1996a, 4).

all possible) for thousands of years.[8] Though it is not explicitly stated anywhere in the industry's guidelines or literature, any justification or claim to significant benefit ought to adhere to one seemingly virtuous principle, namely that the claim is true. I shall make the reasonable assumption throughout that a false justification does not merit consideration toward an acceptable framework for nuclear power in general, or the long-term disposal of radioactive waste in particular.

4.1.1 Justification from Sufficient, or Maximum, Net Benefit

The International Atomic Energy Agency — of which Canada is a member and adherent — is very explicit in stating that 'net benefit' is the overriding criterion for the justification of nuclear power. In their "Basic Safety Standards for Radiological Protection" document, the IAEA states that:

> 2.20. No practice or source within a practice should be authorized unless the practice produces sufficient benefit to the exposed individuals or to society to offset the radiation harm that it might cause; that is: unless the practice is justified, taking into account social, economic and other relevant factors (IAEA, 1996a).

> 3.4. The form, scale, and duration of any such protective action or remedial action shall be optimized so as to produce the maximum net benefit, understood in a broad sense, under the prevailing social and economic circumstances (IAEA, 1996a).

The obvious discrepancy between the two quotes is the use of 'sufficient net benefit' and 'maximum net benefit.' These are not interchangeable. A dictum to *maximize* net benefit will presumably lead to decisions that trade some safety for profit so long

[8] The two other claims — that nuclear power is 'reliable and affordable' — will not be addressed directly here, since in the main this thesis is about applied environmental ethics, though arguments that undermine these claims will be offered in the following sections.

as such decisions do not exceed the minimum safety threshold; in contrast, if one is bid only to seek *sufficient* benefit, then a safety margin above the minimum threshold may be acceptable for the industry. So which net benefit option does the IAEA take to be the driving assumption when making a cost-benefit analysis for the acceptability of nuclear power? Without further clarification from the IAEA on which option here it is difficult to advance the discussion. I find that this lack of clarity (or, at worse, deliberate obfuscation) is a significant and re-occurring impediment to discussing and understanding the issues that undergird the nuclear power debate.

Regardless, progress on the topic can still be made if we question some of the underlying assumptions for both net benefit approaches. It is important to ask: sufficient or maximum net benefit *for whom*? Are we talking about a net benefit for the nuclear industry, or benefit for the current population that uses nuclear-generated electricity? The answer will presumably be dependent on how much safety we are willing to sacrifice for affordable electricity. In a strict interpretation the qualification means that there is no lower-bound safety threshold below which nuclear power would not be justified. In practise, however, eliminating all costly safety features would be unacceptable, even if such omissions genuinely lead to the maximum net benefit. ('Net benefit' is taken to be both profit and affordable long-term electricity production after the costs of safety, security and operation have been deducted.) Rather, I think a charitable and reasonable interpretation of that qualification means that the nuclear power industry can be justified in lowering safety measures if the margin between costs and benefits becomes too narrow. While I am reticent to employ such vague claims, we cannot do much better without clearer principles from the nuclear industry. Nevertheless, Canadians have recently seen this line of reasoning put into action. On November 18th, 2007, Linda Keen (President of the Canadian Nuclear Safety Commission, a nominally independent[9] safety regulator) ordered the Chalk River NRU nuclear reactor to close "over safety concerns about the emergency power system not being connected to cooling pumps, as required to prevent a meltdown during disasters

[9]Ideally the CNSC should be independent in the sense that its decisions regarding the safety and licensing of nuclear reactors is not biased by interests advanced by the nuclear industry which might compromise CSNC's role as regulator of the industry.

such as earthquakes."[10] These are clearly undesirable, and all safety measures should be in place to minimize the risk of their occurrence. However, the Chalk River reactor produces a significant quantity of the world's medical radioisotopes used for imaging tests of cancers and other medical ailments. If the reactor is kept 'offline' people may — for lack of accurate diagnoses — die, both nationally and internationally. The decision problem here is a matter of weighing the costs of ensuring reactor safety procedures are met against the loss of medical isotopes, and the loss of revenue therefrom. Despite the safety measure concerns, the Minister of Natural Resources, Gary Lunn, decided that the lack of isotopes was the more pressing need and directed the CNSC, on 10 December 2008, to reopen the site. Linda Keen refused. An emergency session of the House of Commons convened on 11 December 2008 and ordered the reactor to restart. (Linda Keen was subsequently fired on 16 January 2009 for not complying with the Minister.) In this case the social or medical circumstances were deemed to be the overriding factor. Whether this was appropriate or not is another matter; I raise the issue to point out how the safety of a nuclear power installation can be overridden by non-safety concerns. It will be important for any justified ethical framework to set a lower bound on such overriding concerns. How much safety can be compromised before the practise becomes inherently unacceptable? Or, is there no minimum level of safety, such that we would be justified in accepting any level of risk of harm if the 'net benefit' is sufficiently large?[11]

4.2 Optimization of Protection (ALARA)

In the previous section I asked whether there is a threshold level of safety that must be maintained. The answer seems, in principle, to be yes. The ICRP-(B) principle bids the industry to keep the likelihood of exposure down to the level of "As Low As

[10] <http://www.cbc.ca/canada/story/2008/01/16/keen-firing.html>

[11] The Chalk River NRU reactor produces not only medical isotopes, but it provides facilities for a variety of nuclear researchers. Shutting down this reactor will have ramifications beyond the medical fields. However, the reactor is more than 50 years old, so an alternative reactor will have to be built shortly if we don't want to leave the medical isotope field.

Reasonably Achievable," or ALARA for short. The ALARA principle is reiterated by the IAEA: a radioactive waste management programme should implement procedures for "(a) keeping the generation of radioactive waste to the minimum practicable, in terms of both activity and volume, by using suitable technology; [and] (b) reusing and recycling materials to the extent possible; ..." (IAEA, 1996b). Of course, we need to ask: *What is reasonable*, *what is achievable*, and what is the *minimum practicable* level? With respect to achievability, we can achieve zero radiation exposure to either humans or the environment from human-produced sources (like nuclear reactors) by not generating any nuclear waste in the first place. Such a scenario would surely satisfy the ALARA principle, but it is hardly acceptable to anyone wishing to benefit from nuclear energy. Once we start generating nuclear waste, however, zero risk of radiation exposure is no longer viable. So we need to know how to determine the reasonably achievable, or minimum practicable, levels. The answer to this question, like so many in the nuclear debate, rests on the meaning of ill-defined terms: what is meant by 'practicable'? Again, like 'reasonably achievable,' any so-called practicable solution seems, for the industry, to require weighing the predicted costs and benefits, and then finding a balance which tips the scale in favour of the benefits.

In Canada the Nuclear Waste Management Organization has amended the ICRP guidelines with two other related conditions for the technical acceptability of a long-term nuclear waste storage facility: a modified ALARA principle and the "defence-in-depth" principle; we'll look at the latter in the next section.[12] The first reads as follows:

ALARA Maintain radiation exposure to As Low As Reasonably Achievable. It is defined as the satisfaction of the following conditions: (a) minimize radiation and radioactive waste through efficient station operations; (b) minimize the release of radioactive material into the environment through effective storage and ventilation systems; (c) minimize exposure to people and the environment by requiring workers to wear protective clothing, and controlling emissions.

One semantic difference to note is that whereas the IAEA and ICRP both use the vague

[12] See the NWMO Fact Sheet: "Health Effects of Radiation and Radioactivity."
<http://www.nwmo.ca/Default.aspx?DN=53648f81-7609-4220-9e95-d45f88bfd7db>

criteria of 'minimum practicable' and 'reasonably achievable,' Canada's principle appears more stringent: the NWMO requires that we *minimize* radiation releases and exposure to people and the environment. The distinction is subtle but important. Canada has, in principle, an obligation to ensure that no more radioactive isotopes enter the environment than are absolutely necessary for the operation of a nuclear power source or radioactive waste site. This lower-bound is potentially discoverable; scientists can determine how much ionizing radiation will predictably be released as a matter of operation, and the standards could be set to that level. Unlike the looser 'net-benefit' criterion used by the IAEA, Canada's ALARA principle does require a lower-bound threshold that cannot be changed by considerations of the social or economic benefit to be gained by loosening the safety threshold, even if the benefit (often financial) is significant. However, despite the slight but significant terminological differences, the intent of both formulations is likely the same in spirit, and this is made evident when we look at the origins of the principle. Regulatory staff from the U.S. Atomic Energy Commission and the ICRP thought that "adding this phrase might discourage licensees from assuming that approaching the permissible limits as a matter of course, rather than trying to reduce levels to a minimum, was acceptable" (Walker, 2000, 32).

It is imperative that the nuclear industry keep the costs of radiological protection down to a manageable (perhaps minimal) level. This is accomplished by managing radiological interventions appropriately. Managing radiological protection is "the process of deciding that the disadvantages of each component of intervention, i.e. of each protective action, are more than offset by the reductions in the dose likely to be achieved" (ICRP 1990). An *intervention*, another term with a specific meaning in this context, is any protective action implemented to prevent exposure to radiation; interventions can include everything from safety suits, dosimetry measurement devices,[13] containment structures around a nuclear reactor, concrete casks for spent fuel, and a deep geological repository for the waste. The common element is that interventions are a cost, and thereby reduce the overall net benefit of the practice

[13]Dosimetry devices measure the dose of radiation emitted by a radioactive source

if they are not sufficiently restrained by the nuclear industry. For this reason an intervention, according to the ICRP, "should be judged on the basis of the reduction in the dose achieved or expected by that specific action, i.e. the dose averted. Thus, each protective action has to be considered on its own merits" (ICRP 1990, p.76). Similarly, the IAEA states that:

> 3.3. In order to reduce or avert exposures in intervention situations, protective actions or remedial actions shall be undertaken whenever they are justified (IAEA, 1996a).

Justification here is, again, portrayed as a matter of weighing the costs and benefits of the action. Quite clearly it is in the industry's interest to keep costs down, and this is almost invariably a matter of reducing safety components. The public question becomes a matter of deciding how much safety we are willing to forego for the use of nuclear power. Without a clearly defined minimum threshold for radiation exposure, leak potential, and minimum probability of failure, there is no non-arbitrary way to limit how much the 'costs' (such as safety factors) can be reduced before they become technically (let alone ethically or socially) unacceptable. This a concern that must be addressed by a nuclear energy policy framework.

There is a further problem for any approach that relies on the 'whenever justified' reasoning for implementing safety factors: *all nuclear waste is entirely a cost.*[14] And yet it is also the lasting primary product of the nuclear power process. (Dr. Gordon Edwards, a mathematician and founder of the Canadian Coalition for Nuclear Responsibility, eloquently expressed the problem: "Electricity is the by-product of nuclear waste production.") Once the waste is produced, there is no financial incentive to manage it from the perspective of the producer; without the prospect of some benefit, it would be irrational to proceed with further safety interventions on the basis of a cost-benefit analysis (containing the waste is, for the most part, a liability).[15]

[14]Not including reprocessing scenarios, as Canada does not reprocess its waste. I will discuss reprocessing shortly.

[15]I say here that nuclear fuel waste is a liability 'for the most part' because it may eventually

For this reason the safety and storage requirements for used nuclear fuel have had to be legislated so that the costs cannot be externalized onto citizenry; the industry, in turn, has implemented a system where a small portion of each electricity bill goes into a trust fund to pay for the nuclear storage facility.

One of the overarching concerns in the used nuclear fuel debate is the matter of balancing long-term safety with the cost of containment. How safe is safe enough? How long does the waste remain harmful? How long must the containment facility remain secure? And what is a *reasonable* cost for the desired degree of safety? While the specific radioactivity of the fuel diminishes over time, the NWMO admits that "the radiotoxicity analysis for used CANDU fuel suggests that this material is a potential internal exposure health risk for more than one million years" (Nash & Dowdeswell, 2005a, p.343)[16]; therefore, to fully minimize the risk, "...one could conclude that used nuclear fuel poses a hazard which needs to be managed for one million years or more" (Nash & Dowdeswell, 2005a, p. 344). How, then, can we either minimize risk, or keep the risk 'as low as reasonably achievable' for one million years? The NWMO's solution is to implement a 'defence-in-depth' approach to the long-term disposal of nuclear fuel waste.

4.2.1 Defence-in-Depth

Minimizing the release, or risk of release, of radioactive waste requires a set of safeguards which are unparalleled in other industries. The waste must be secured and protected from humans and the environment *for a time-period longer than the entire length of human civilization which has thus far come to pass.* Ensuring the 'safe' isolation of waste for that long obviously cannot be done with certainty, so provisions must be made that attempt to minimize the likelihood of either intentional or accidental release. The nuclear industry recognizes this limitation and has imple-

become a source of fuel if Parliament and the nuclear industry opt for a reprocessing programme in the future.

[16]See (Mehta et al. 1991; AECL 1994) in NWMO final.

mented a defence-in-depth principle in order to satisfy the ALARA condition. The Defence-in-Depth principle states that

> 2.35. A multi-layer (defence in depth) system of provisions for protection and safety commensurate with the magnitude and likelihood of the potential exposures involved shall be applied to sources such that a failure at one layer is compensated for or corrected by subsequent layers, for the purposes of: (a) preventing accidents that may cause exposure; (b) mitigating the consequences of any such accident that does occur; and (c) restoring sources to safe conditions after any such accident (IAEA, 1996a).

The approach is simple in theory: build multiple barriers of defence in case one of the earlier barriers fails. In Canada the "initial barriers are the ceramic casing of each fuel pellet, the special metal alloy encasing each bundle of fuel pellets, and the concrete containment structure that holds the fuel bundles in dry storage" (Nash & Dowdeswell, 2005a). Such layers of defence have not always been the preferred method of handling the long-term waste. Some proposals have included sending the waste into space, burying it in an ocean or lake, disposing of it in volcanoes, or keeping it on-site at the generating reactor. None of these options provide much in the way of multiple layers of defence.[17] As we saw in the previous chapter, after some consideration of the viable options, the NWMO concluded that burying the waste in reinforced casks 500 to 1000 meters deep in tectonically inactive rock formations of the Canadian Shield is thought to be the 'best, safest, long-term option' (i.e., presumably the ethically 'least-bad' option) by the international community (Shrader-Frechette, 2002b, 95).[18]

[17]The space option was interesting, however, until one considers the fact that rockets have a 6% failure rate, and would be exorbitantly expensive given the sheer volume of waste that we currently possess.

[18]We cannot, strictly speaking, literally dispose of the waste in a way which does not entail some residual risk of harm; the possible exception, though, might be sending the waste into space (but that was dealt with above). Rather, we need either to store or manage the waste, hopefully in a manner that at least minimizes risk to humans and the environment over time. There is some debate over the semantics of the right terminology here, but I shall simply stipulate that the *storage* is merely the isolation of nuclear waste, while the *management* of nuclear waste involves some level of active human involvement in its containment over time (e.g., monitoring and retrievability).

This proposal, known as Adaptive Phased Management (APM), also has the provisions that the waste be monitored and retrievable (as opposed to completely sealing it in the rock) in case future people choose to reprocess the waste as nuclear fuel. This will take 60 to 100 years to implement if a suitable site can be negotiated (Nash & Dowdeswell, 2005a).

Underlying this type of approach is the assumption that minimizing risk constitutes the extent of our ethical obligation; after all, minimizing risk is the best option short of not producing any nuclear waste — and that genie is already out of the bottle. It is a common belief — I dare say the belief approaches dogma — in the industry that, if we develop safe methods of nuclear waste storage and safe reactors, all-the-while generating electricity and a profit, then any social and ethical concerns become irrelevant (or irrational), and lack substantial merit. That is, *a technical solution is the ethical solution.* The International Atomic Energy Agency (IAEA) has expressed this disturbingly cavalier attitude regarding the safety and reliability of nuclear reactors and nuclear waste management options quite succinctly: "The technical and scientific communities today generally seem to be convinced that such solutions already exist, at least in principle, and that these solutions will meet all reasonable demands" (IAEA, 1992, 189).[19] Where some risk is unavoidable, compensation can be offered to communities *willing* to bear that risk. Engineers will also try to build systems with very low failure probabilities so that if the chance of harm from failure (meltdown, leaks, etc.) is low enough, our ethical and social obligations will have been paid in full — this is what it means technically to minimize risk. Thus, (so continues the reasoning), if the public has any fear of radioactivity and radioactive waste leaks, it likely "arises from a fundamental apprehension of radioactivity, a lack of knowledge about what radioactive waste is and how it is currently managed and a lack of understanding of how radioactive substances behave in nature" (IAEA, 1992, 198). Our ethical misgivings therefore arise from technical or scientific ignorance. The IAEA principles (A) — (C) are clear manifestation of this belief.

[19] See Bernard Cohen's book *The Nuclear Energy Option* (Cohen, Cohen, 1977) for a sustained defence of this sentiment.

Recognizing that some people might disagree with the whole-hearted adoption of a solely technical solution — which also privileges and authorizes expert opinion and action — the author of the IAEA report (Hans Blix, of Iraq weapons fame) continues by stating that: "it *may* be presumptuous to assume that today we possess all the fundamental knowledge to take responsibility for every imaginable consequence to future generations" (IAEA, 1992, emphasis added). He's wrong. It *is* presumptuous. However, the whole-hearted assumption that the technical solution is the only solution is somewhat understandable, given that nuclear power is largely a technical or engineering task, and engineers sometimes tend not to appreciate extra social or ethical constraints on engineering activities. Flynn and Dotto (1995) have astutely captured this notion: "Initially, the waste problem was conceived to be fundamentally technical in nature, and scientific research and technical assessment were adopted as the primary tools for developing solutions. The idea that the public might intrude in this process and take an active role was anathema to many of those mandated to manage nuclear wastes" (Flynn & Dotto, 1995, 92). Recall further that Canada began mining uranium in the 1930s, constructed and operated its first nuclear research reactor (the NRX) in 1947, and its first large-scale commercial reactor complex (Pickering) in 1966. However, no commission regarding the issue of long-term nuclear fuel waste storage was conducted until 1977, and it was not until 2002 that the *Nuclear Fuel Waste Act* was established to legislate the long-term management of nuclear fuel waste. The consensus in the industry beforehand was that the management of spent fuel was simply a technical problem awaiting a technical solution. Any subsequent ethical or social principles would simply impose constraints — uninformed often, fear-driven constraints — on what types of technical solutions could be had.

4.2.2 Minimizing and Managing Risk

Weighing the costs and benefits of nuclear power is very often conceived of in terms of managing risk. Insurance companies 'manage risk.' They evaluate the likelihood for a type of potential damage, and charge money to manage that risk accordingly.

"The calculation of [risk] is based on many years of experience; the losses are, *statistically, predictable*" (Scheider, 2001, emphasis mine). Automobile insurance is a good example, as they can "know in advance how many and what kind of accidents they are insuring motorists for, based on the data from past years"(Scheider, 2001, 205). When a person wants automobile insurance, the insurer evaluates the likelihood of an accident (or rather various loss scenarios) given the individual's age, health, and driving record, and then prices a policy accordingly.

But this type of risk management does not apply to the nuclear industry "because the stakes are incredibly high and because there is no statistical basis for making the assessments" (Scheider, 2001, 206). Thus, ideally every possible precaution should be undertaken to ensure that a serious accident has *no chance* of even happening. But of course, this is entirely unrealistic: "It is cost-prohibitive to take *every possible precaution*, although often those words are used. Every *affordable* precaution is taken. And even if every possible precaution were taken, it is not certain that there would be zero chance of a disastrous accident" (Scheider, 2001). And yet managing risk is precisely what the nuclear industry is attempting to do, despite the fact that there "is no agreement about how to assign probability based on evidence that is not statistically valid because it consists of samples of zero, or one or two actual events" (ibid., 207).[20] How can we make sense of 'minimum risk' under these conditions?

The magnitude of this problem is not lost on the insurance industry — tellingly, no insurance company will insure a nuclear power plant or citizens from a nuclear accident. The coverage has to come from the government. According to the Nuclear Liability Act, the nuclear industry is liable only for "basic insurance for such term and for such amount not exceeding seventy-five million dollars."[21] The industry only needs to cover a *mere* $75 million dollars in the event of a serious nuclear accident, while the taxpayers are liable for the remainder: This is certainly one way of reducing nuclear power costs and managing one's risk of financial loss. The Act also covers

[20] Scheider continues: "Some risks are taken because the cost of avoiding them isn't worth it; some are not taken because the cost of taking them is predictably too high" (Scheider, 2001).

[21] See the Nuclear Liability Act; <http://lois.justice.gc.ca/en/N-28/>.

nuclear installations "in which nuclear material is stored other than incidentally to the carriage of the material," so any accident at a radioactive waste facility is also limited by this liability, even if the costs of cleanup greatly exceed that amount. Moreover, who will pay for the cleanup if a serious accident occurs at the facility in three hundred years or more? Should future people, let alone the present generation, have to bear that potential cost? Can we guarantee that they will never have to pay for our radioactive waste? An honest approach to adjudicating the costs and benefits of nuclear power would include market prices for insurance coverage; this task remains to be done, and my suspicion is that, if implemented, nuclear power would not be affordable.

So far we have looked at the justification and optimization of a nuclear power practise. The final technical condition for the industry's utilitarian justification of nuclear power is establishing a threshold for individual dosage and acceptable harm. I will turn to that third condition in the following section. Recall that, if these principles are satisfied, then the nuclear industry is deemed on its own terms to be acting ethically. As we have seen, however, it is not clear what satisfying those principles in practise means specifically; nor are they the only conditions that must be met for an ethical framework to be acceptable.

4.3 Radiation Dose Limits in Canada

> Q9. Is a reasonable attempt being made to determine, in so far as it is possible to do so, the **costs, harms, risks, and benefits** of the options under consideration, including not just financial costs but also physical, biological, social, cultural, and ethical costs (harm to our values)?

One of the harms which might result from the operation of a nuclear power reactor, or radioactive waste management facility, is an increased exposure to ionizing radiation; such radiation can disrupt the immune system, induce certain types of cancer, or cause death if the immediate dosage is large enough. Obviously, we want to mitigate such possibilities. For this reason, part of the industry's utilitarian justification for nuclear power stipulates, in principle ICRP-(c), that "the exposure of individuals ... should be subject to dose limits ... aimed at ensuring that no individual is exposed to radiation risks that are judged to be unacceptable ... (individual dose limits).[22] In this section I examine what is meant by that claim.

The Nuclear Safety and Control Act (NSCA) and its Radiation Protection Regulations prescribes the effective radiation dose limits in Canada.[23] The effective dose to the general public and non-nuclear workers should not exceed 1 milli-Sieverts (mSv) per annum from all combined nuclear-related sources, but it excludes exposure from natural background radiation and medical procedures. Nuclear workers are allowed an effective exposure of 50 mSv per annum. Due to the increased risk of developmental damage, due a fetus's rapidly dividing cells, a pregnant nuclear worker is subject to stricter dosage controls in order to mitigate any potential harm to the fetus. Figure 4.1, from the NSCA, shows the current limits to various nuclear workers and the general public.[24] In the case that a nuclear worker has exceeded the allowable effective dosage, the nuclear operator has responsibility to report the incident to the Canadian Nuclear Safety Commission (CNSC) for review.

Nuclear reactors and spent nuclear fuel are not the only place where we find radioactive sources. In fact, radiation is everywhere — it can be found in the ocean, rocks, mines, our basements (especially radon), plants, sources inside the human body, cosmic rays (especially prevalent during airplane flights), and the Earth's crust.[25] All of the natural — *i.e.* non-human-made — sources are collectively termed "background radiation." The average annual exposure from natural background radiation in Canada is 1.7 mSv, though this varies significantly depending on one's geographical

[22]See ICRP's "Radiological Protection" report summary, 1990

[23]See Canada's Radiation Protection Regulations, SOR/2000-203: <http://laws.justice.gc.ca/PDF/Regulation/s/sor-2000-203.pdf>.

[24]The inclusion of 'pregnant nuclear energy worker' in both rows 1 and 2 of figure 4.1 is problematic, and it may be due to a clerical error; for the time-being we ought to assume that row 1 should only include 'non-pregnant energy workers.'

[25]At present there is a large amount of uranium dissolved in the ocean and people have proposed that we extract this uranium content for use in our reactors (Ku et al., 1977).

TABLE

Item	Column 1 Person	Column 2 Period	Column 3 Effective Dose (mSv)
1.	Nuclear energy worker, including a pregnant nuclear energy worker	(*a*) One-year dosimetry period	50
		(*b*) Five-year dosimetry period	100
2.	Pregnant nuclear energy worker	Balance of the pregnancy	4
3.	A person who is not a nuclear energy worker	One calendar year	1

Figure 4.1: Nuclear Safety and Control Act effective dose limits. (Radiation Protection Regulations: SOR/2000-203)

location and the number of airplane flights undertaken in a year (Grasty & LaMarre, 2004). By way of comparison, a single mammogram is 3 mSv, the 70-year dose for people living in rural Ukraine near Chernobyl is 14 mSv, one year on the International Space Station is 170 mSv, and the mean dose for atomic bomb survivors is, or was, 200 mSv (Brenner et al., 2003).

A brief note on radiation measurement units is in order before we continue. In the past one-hundred years or so since the discovery of radioactivity a number of units of measurement have been employed, and while standardization is nearly complete, much of the literature still contains different units which need to be converted. Each of the units is basically a measure of either absorbed dose, equivalent dose, or effective dose. *Absorbed dose* is the physical energy (total ionizing radiation) 'deposited' by the radiation in a kilogram of substance, like a human, animal, or cell tissue. Absorbed dose is currently measured in Grays (Gy), and is expressed in units of joules per kilogram (J/kg); the previously used unit was the *rad*, and $1Gy = 100rad$. The actual physical quantity of radiation, however, does not accurately reflect the biological effects because different types of radiation preferentially damage different cells and organs, and for this reason absorbed dose is converted into biological equivalent and

Table A3-3 External Radiation from Used CANDU Fuel as a Function of Time

AGE OF USED CANDU FUEL (years)	UNSHIELDED EXTERNAL RADIATION FIELD AT 0.3 m (mSv/h)	EXPOSURE TIME TO REACH PUBLIC DOSE LIMIT OF 1 mSv/a
50	1,150	3 seconds
100	360	10 seconds
200	37	97 seconds
500	0.82	1.2 hours
1,000,000	0.009	110 hours

Figures shown for an average burn-up of 7,800 MW days per tonne of uranium.

Figure 4.2: NWMO external radiation time limits for annual dose.

biological effective doses. The *equivalent dose* is measured as the absorbed dose weighted for harmful effects of different radiation.[26] Each tissue is also differentially susceptible; the *effective dose* is a measure of the equivalent dose weighted for harm to different tissues.[27] Both the equivalent and effective dose are currently measured in *sieverts* (Sv), and this SI derived unit replaces the previously used unit of "röntgen equivalent man" (rem); one sievert = 100 rems. Even a fraction of a sievert is a significant quantity of radiation so most measurements are made using milli-sieverts (mSv). Biological effects are the most relevant for radiation protection purposes, so the biological effective and equivalent dose are used to express the radiation effects on humans and animals, and hence all of the radiological protection guidelines are given in sieverts (or its historical counterpart, the *rem*). It is worth noting that very little physical energy is needed to produce a biological effect:

> A gamma dose of 400 mrems [4 mSv], which is very large in terms of biological hazard, corresponds to 4 J/kg, which would be insufficient to raise the temperature of a kilogram of water as much as 0.001°C. This fact shows that radiation affects the function of the cells by action on certain molecules, not by a general

[26] This is typically called a Quality Factor (Q), and the equivalent dose is expressed as the weighting factor w_R.

[27] The effective dose uses a tissue weighting factor of w_T.

heating process (Murray, 1993, 196).

Let us now see whether there is a "exposure dosage," such that amount above which exposure would be unacceptable from a human standpoint.

4.3.1 Is there a minimum individual dosage threshold?

This brief discussion permits us to address the central question of radiological protection and the acceptability of radiation exposure: is there a safe level, or threshold, of radiation such that any exposure below it will not cause biological harm? Despite its centrality to the issue, it is a difficult question to answer directly as any answer depends upon a number of basic assumptions underlying the employed statistical model.

There was recently a debate about whether any radiation exposure is potentially harmful, or whether there is some minimal threshold below which any radiation is statistically negligible, but the issue has largely been supplanted in favour of the so-called linear no-threshold model of exposure. According to this *linear no-threshold model*, there is no safe level of radiation, and risk of harm from radiation is directly proportional to the level of exposure. That is, doubling the amount of radiation received doubles your risk of radiation-induced damage to cells, tissue, and chromosomes. This assumption is currently endorsed by most independent researchers and it undergirds the U.S. National Research Council's influential report on the Biological Effects of Ionizing Radiation":[28]

> The BEIR VII committee concludes that current scientific evidence is consistent with the hypothesis that there is a linear dose-response relationship between exposure to ionizing radiation and the development of radiation-induced solid

[28] This report can be found online at National Academy Press website: <`http://www.nap.edu/openbook.php?isbn=030909156X`>. It provides an excellent introduction to the current state of low-level radiation knowlege and research.

> cancers in humans. The committee further judges it unlikely that a threshold exists for the induction of cancers but notes that the occurrence of radiation-induced cancers at low doses will be small (BEIR VII, p. 10).

The United Nations reaffirms this claim:

> According to the United Nations Scientific Committee on Effects of Ionizing Radiation (U.N.S.C.E.A.R.), the International Atomic Energy Agency (I.A.E.A.), and other scientific groups, natural-background radiation causes about 3 percent of fatal cancers — roughly 18,000 annual U.S. deaths. As the U.S. National Academy of Sciences reaffirmed in June, no dose of ionizing radiation is completely safe, no matter how small or how natural" (Shrader-Frechette, 2005)

According to Brenner *et al.* (2003), epidemiological data indicates that an acute dose of 10-50 mSv, or a protracted dose of approximately 50-100 mSv, will lead to an increase in some types of cancer (Brenner et al., 2003). The risks are also affected by age and genetic status; young people and people with certain genetic predispositions are more susceptible. For example, a diagnostic *in utero* dose of 10 mSv to an embryo or fetus is known to increase the risk of childhood cancer. Prolonged exposure of 6 mSv in Canadian radiation workers is known to increase mortality risks and solid cancers. And females under 20 exposed to 108 mSv in 25 doses during diagnostic x-rays were statistically at excess risk of developing breast cancer (Brenner et al., 2003).

Risk, in this context, is defined by the U.S. National Research Counsel as the "probability that an individual develops a specified disease over a specified interval of time, given that the individual is alive and disease free at the start of the time period" (BEIR VII, p.260). One expects the risks of low doses to be comparably lower than a high dose, but quantifying the risk of low doses requires a progressively larger sample size. For example, "if the excess risk were proportional to the radiation dose, and if a sample size of 500 persons were needed to quantify the effect of a 1,000-mSv dose, then a sample size of 50,000 would be needed for a 100-mSv dose, and [approximately] 5 million for a 10-mSv dose"(Brenner et al., 2003).

Our fundamental inability to quantify precisely the cancer-risk from low-dose exposure to radiation does not imply that the risk is discountable. It is "unlikely that we will be able to directly and precisely quantify cancer risks in human populations at doses much below 10 mSv. Our inability to quantify such risks does not, however, imply that the corresponding societal risks are necessarily negligible; a very small risk, if applied to a large number of individuals, can result in a significant public health problem" (Brenner et al., 2003). This is a sobering conclusion. "At present, we cannot be sure of the appropriate dose-response relation to use for risk estimation at very low doses" (ibid.). And if we don't know this relation, we cannot precisely quantify the elevated risk of harm imposed on the general population by nuclear power generation.

This position has important ramifications for the justification of nuclear power. The industry claims that its practise will not raise an individual's level of exposure to an extent greater than the background radiation level. The reasoning behind this claim is the hypothesis that there is a threshold below which radiation has *no* ill-effects. Both the current scientific literature and abidance by a precautionary principle have undermined this claim. Thus, if the linear no-threshold model is true, then nuclear power *increases* individual stochastic (i.e., statistical) risk of developing cancers; the extra exposure is additive on the background levels and medical exposures. The minimization criterion ensures that any increase in exposure is kept 'as low as reasonably achievable,' so long as the facility and safeguarding institutions operate *as designed*. But in any complex system, accidents are normal; we should expect some failures, and be surprised when they don't happen, or aren't being reported (Perrow, 1999). Perhaps the important question that we need to ask is the following: are we willing to accept the elevated risk of radiation exposure *if* the facility or safeguards were to fail? To answer this we need to know what will the exposure be in the event of various failure scenarios. Unfortunately, this information seems not, at least publicly, to have have been calculated.

And risk of harm is not evenly distributed. As Kristin Shrader-Frechette reminds us: "Even if one is willing to grant that human life and health ought to be traded for technological benefits, there is still the problem that the liabilities of such a tradeoff are not borne equitably" (Shrader-Frechette, 1980, 35). For instance:

> If a child and an adult each receive one rad of total body radiation, the child (according to government calculations) is three to six times more likely than the adult to contract cancer because of this exposure. ... [This consequence assumes] an even greater magnitude when one realizes that radiation exposure is not short-lived, but cumulative, and that the average lifetime of a nuclear plant is 30 years (Shrader-Frechette, 1980, 34).

Furthermore, merely living near a nuclear reactor also poses an elevated risk:

> Persons living within a 50-mile radius of a reactor also constitute a minority whose rights to equal protection are compromised. Public policy makers clearly admit that, because of their proximity to a nuclear plant, these people bear a cancer and genetic damage risk up to as much as fifty times greater than that borne by the general US public (Shrader-Frechette, 1980, 34).

The US government estimates that "every rad of radiation causes 0.002 genetic deaths among offspring of irradiated ancestors" (Shrader-Frechette, 1980, 35). Thus, if everyone near a plant receives the maximum permissible dose of 0.5 rem, then over the 30-year period of a reactor we can expect 3% of the population to die from genetic disorders induced by exposure to radiation from the reactor (Shrader-Frechette, 1980).[29] This 3% of the future population does not get equal protection.

[29]Shrader-Frechette (1980) describes an interesting instance of 'defining man-made radiation as normal and therefore moral' because it does not exceed the background levels of radiation. "The US stopped above-ground testing of nuclear devices, in part, because of its policy of not polluting the atmosphere with radiation. Yet reliable government documents reveal that global fallout adds only 0.004 rem/year of whole body exposure, while current atomic plant radiation standards permit 0.5 rem/year of whole body exposure" (Shrader-Frechette, 1980, 37).

4.4 The Unacceptability of a Cost-Benefit Analysis

What we now see, upon analysis, is a surprisingly dubious notion of a 'cost-benefit' analysis. Nuclear power is justified — according to industry's approach — if the electricity and other benefits provided by our nuclear reactors outweigh the costs and risk of harm associated with its operation. Up to this point we have been critically evaluating the industry's cost-benefit methodology, and found it seriously wanting. Its format cost-benefit table only includes risks and not direct costs on the negative side of the ledger. The risks are stated vaguely whereas the benefits are stated specifically, the concept of risk itself is deeply unclear and contested in the industry, the probabilities of health problems upon leakage or difficulty with waste storage are quite significant, and the time-lines for effectiveness of safe storage are beyond anything any previous society has ever had to deal with, and so only add to the dangers and concerns on the cost side of the equation. In addition to these particular problems, there is also the following generic issue:

> "Cost-benefit analysis assumes that everything, including human life, may in principle be given a value by which its worth can be compared with that of anything else, even though the actual measurement of such value may be difficult in practice" (Sumner & Gilmour, 1995, p.244).

We cannot overstate the importance of this point. How much is another human life worth? How much are the lives of future generations worth? What is the cost — financially, emotionally, and genetically — of getting cancer from nuclear operations? How do we put a quantitative value on any of these concerns? What is the actual risk of failure? What is the likelihood of getting cancer from the additional radiation releases from nuclear power operations? How can we even pretend to be comfortable with these safety options for storage, given human fallibility and the incredible stretches of time in view? One might be tempted to toss such concerns aside because we *do* make cost-benefit analyses all the time. For example, we decide that the benefit of driving a car to work is worth the small risk of crashing, even though we ourselves don't have quantitative data about the likelihood of a crash on that particular day, and we may also rely on the safety features, like multiple air-bags, to keep us safe in the event of an accident. By getting into the car and driving, we accept the associated risk, namely anything from some bumps and bruises to death. By-and-large, our use of nuclear power shares similar reasoning. We accept the risk associated with nuclear power by the fact that we have made the determination that its benefits — electricity, jobs, and our perception or ill-founded hope of it being a 'clean, reliable, affordable' operation — outweigh the costs we might incur if a reactor or related nuclear accident occurs. To minimize accidents, we implement safety features that reduce both the likelihood of an accident and the potential damage in case an accident does occur. These safety features are guided by the ALARA and DEFENCE-IN-DEPTH principles. But note that we make this determination with neither solid quantitative data about the likelihood of failure (and likelihood of developing cancer) nor full information about the extent of damage that may be caused by the release of radiation. Despite the concern raised in the above quotation, we do make cost-benefit decisions without explicit quantitative information.[30]

So what is the problem with making a cost-benefit analysis for nuclear energy? Several conditions separate the nuclear cost-benefit decision from, say, our automobile example. First, when you choose to drive, you accept the risk of accident voluntarily. The same is not always true if we have a nuclear accident. While people who directly benefit from nuclear power's electricity may be said to have consented to the risk voluntarily (assuming they know the full risk), people living 'off-the-grid,' or any member of a future generation, do *not* voluntarily consent. Yet they are still subjected to the risk of harm, perhaps even more so than us, when it comes to the issue

[30]For a good example of this we need only look at the 'clean'-benefit aspect of our decision. So-called 'clean' energy is taken to be preferable than 'dirty' energy. If nuclear is cleaner than coal energy, then nuclear is to be preferred. As simple as this example sounds, it is this line of reasoning that many people use to justify their support for nuclear power. Of course, this decision also rests upon the truth of the claim that nuclear power is 'clean'; we've established that this is in fact false at best, and disingenuous at worse. Only after we weigh a multitude of factors, and examine the truth of the claims, does the outcome of cost-benefit analysis becomes clearer.

of radioactive waste. Second, there is no ability to opt-out of the action. I can choose whether or not I want to drive, but I cannot choose to remove myself from the dangers of nuclear power. Third, if an accident does occur, it may not be localized solely to the region inhabited by those who have consented to the risk; whereas a car accident only affects a small number of people in a small region (like a road intersection), a nuclear accident may make thousands of hectares of land uninhabitable and affect everyone in the region for eons. Fourth, unlike a car accident, the region affected by a nuclear accident may remain a hazard for hundreds or thousands of years and, due to the nature of radiation, commencement of direct clean-up may be impossible for decades. The Chernobyl accident is a good example — a concrete cask has had to be constructed over the reactor core because the radiation inside is so lethal that no cleanup operation is possible until the radioactive material has decayed and cooled sufficiently; the cask is an attempt to prevent the radioactive material from leaching into the environment, but when a cleanup becomes possible, it will merely be a process of moving the highly radioactive waste into a more secure location so that it can continue its biologically harmful decay process. Fifth, whereas one can seek compensation in the case of a car accident, it might not be possible to make claims for compensation resulting from, say, nuclear power-induced cancers or related harms, because proving that a cancer was caused by the operations of the nuclear industry is exceedingly difficult — the cancers likely won't develop for several years, and it is not possible yet to rule out background radiation as a cause. So while the industry's operations may have resulted in your diminished health, it won't cost them anything. These reasons — inability to quantify important variables like the value of human life, lack of voluntary risk adoption for some, lack of an ability to opt-out, the potentially non-localized nature of the harm, the duration of the risk of harm, and the lack of compensation for damage incurred — are significant considerations that undermine the applicability of a cost-benefit analysis of the justification of nuclear power. Aspects of costs and benefits are, of course, relevant. But to pretend that such a method captures *everything* important, or to pretend that Canada's current nuclear generation and storage practices meet the standards of such a method, is just that: pretence which is at odds with the facts.

Chapter 5

Ethical Analysis

One helpful and illustrative way of conceiving the relevant ethical problems is to imagine that we are sending the radioactive waste to the future in a way analogous to consigning a train to carry harmful material to a distant (in this case temporal) destination. Richard and Val Routley (Routley & Routley, 2000) offer a lucid articulation of this scenario:

> THE TRAIN PARABLE: A long distance country train has just pulled out. The train, which is crowded, carries both passengers and freight. At an early stop in the journey, someone consigns as freight, to a far distant destination, a package which contains a highly toxic and explosive gas. This is packed in a very thin container which, as the consigner is aware, may well not contain the gas for the full distance for which it is consigned, and certainly will not do so if the train should strike any real trouble, for example, if the train should be derailed or involved in a collision, or if some passenger should interfere inadvertently or deliberately with the freight, perhaps trying to steal it. All of these sorts of things have happened on some previous journeys. If the container should break, the resulting disaster would probably kill at least some of the people on the train in adjacent carriages, while others could be maimed or poisoned or sooner or later incur serious diseases (Routley & Routley, 2000, 185).

The hazardous material is, for our purposes, nuclear waste and the train tracks lead not to a specific physical location but rather to some future temporal destination, let's call it "eventual radioactive safety." One addition must be made to make the parable a better analogy to the nuclear waste case. Unlike train accidents that occur today, where we can clean up the *localized* hazard and seek compensation for any damages, if our radioactive train fails then *everyone* further down the tracks is at greater risk of being harmed (it is temporally non-localized), and there is no way for them to seek compensation for the losses or damages incurred.

In the previous chapter we saw that the industry's justification for placing the waste on the train and sending it down the temporal tracks is based on a cost-benefit analysis coupled with two provisos: keep the risk 'As Low As Reasonably Achievable,' and build the repository with multiple layers of defence to protect both humans and the environment. But these are not the only conditions that must be satisfied in order to make a nuclear waste repository, and subsequently a nuclear power industry, ethically acceptable. How certain can we be that our radioactive train will not fail throughout the lifetime of its journey? Is it acceptable to burden future people with our waste, given that they cannot voluntarily consent to the burden? Does our repository and nuclear power programme 'respect life and nature,' according to aboriginal principles and beliefs? Finally, does the NWMO's Adaptive Phased Management approach abide by the precautionary principle, a principle which bids us to avoid risk of harm unless that risk is ethically justifiable? In this chapter I will describe the content of these ethical concerns in the context of the train parable above, and show that each of these ethical problems poses serious difficulties for the ethical justification of producing nuclear waste. The next chapter will examine in detail the NWMO's remaining major ethical principle, namely, the *fair* distribution of nuclear waste across multiple generations. (For the full list of ethical principles, please refer back to the NWMO's ethical framework presented in the first chapter.)

5.1 Uncertainty

> Q4: . . . have [the] limits to the current state of knowledge, in particular gaps and areas of uncertainty in current knowledge, been publicly identified and the interpretation of their importance publicly discussed and justified?

As the parable suggests, our nuclear waste containment facilities "may well not contain [the waste] for the full [temporal] distance" and will certainly not if it encounters willful or natural interference. The 'may' is important. It could very well be the case that our containment system secures the waste in perpetuity and never releases its contents; but it may well not, especially given the time-frames in view. We can never know with certainty, as our knowledge about whether or not the radioactive train will spill its contents is limited to several types of uncertainty.[1]

Uncertainty is broadly defined "as an event about which there is not complete, reliable scientific and mathematical data and thus whose likelihood of occurrence is unknown and therefore a matter of models and conjectures" (Shrader-Frechette, 2003). There are at least six types of uncertainty relevant to issues relating to nuclear waste disposal:[2]

1. *Framing*: A frame is the set of assumptions used for interpreting data and posing questions. For instance, U.S. experts deciding whether to recommenced the Yucca Mountain site for long-term storage were only given the options of "suitability finding" or 'unsuitability finding," with the addendum that if there is 'not enough information' then a suitability finding should be chosen; this two-value frame, of course, leaves no middle ground. A three-value option might be better, but there is no algorithm in general that can resolve frame-uncertainty. Framing is largely a matter of setting the boundary conditions

[1] I only use 'technical' uncertainty, and do not include 'scientific' uncertainty, because we understand the nature of radioactivity quite well, so the science is much less controversial than the technical designs we build to contain the waste.

[2] See (Shrader-Frechette, 2003) for further discussion of the types of uncertainty relevant to the nuclear waste case.

within which the problem or set of questions will be answered. Restricting the boundary of investigation too narrowly will likely leave out viable options, but leaving the scope too broad will direct resources to some minimally viable alternatives; setting the boundary, therefore, is constrained by the available financial resources and time-frame within which a decision needs to be made.

2. *Modeling*: Models of long-term waste storage (in the range of 1,000 to 1,000,000 million years) cannot be verified in the sense of conforming to facts; at best they can provide a range of values and distributions, but these have been shown to vary by several orders of magnitude depending on which assumptions a particular model uses.

3. *Inference-options*: These are the inferences scientists make when deciding "what data to omit, how to classify data, when measurements are flawed, when extrapolation is valid, which simplifications are valid, and so on" (Shrader-Frechette, 2003). One example is the IAEA's controversial decision that they did not need to collect data on long-term carcinogenic or genetic effects of people close to the Chernobyl accident; later studies by other scientists revealed a 100-fold increase in thyroid cancers in people 400km away from the accident 8 years after, as well as a doubling in germ-line mutations.

4. *Statistical or parameter*: Models are only as good as the data; errors of this sort arise either because of an inadequate sample size, or an inability to minimize Type I (false-positive) or Type II (false-negative errors).

5. *Decision-theoretic*: This arises because "Decision theory is a mathematical framework for choosing among alternative actions, given that one knows the probability p that each alternative will occur and the value or utility u associated with it. A major uncertainty in decision theory is whether, in a given situation, one should choose the course of action that maximizes average expected utility or welfare (expected utility $= p \times u$), or that minimizes the chance that the worst outcome will occur" (Shrader-Frechette, 2003).

6. *Policy-implementation*: Refers to uncertainty regarding how policies are actually implemented, as this depends to a large extent on impartiality (and competence) of regulatory agencies, the resources they are granted, respect for free informed consent, due processes, and appropriate compensation.

Each of these is important in analyzing and understanding the particular limits to our knowledge and certainty regarding nuclear policy issues. For the purposes of the present discussion, however, let us broadly classify types one to five as forms of technical uncertainty, and the sixth as a form of political uncertainty. Technical uncertainty, for the most part, arises because we do not have complete information about how our waste containers and management facilities will behave over long periods of time. That is, we cannot be sure that our radioactive train will remain structurally secure for the duration of its journey. It is always possible that the canister materials we use to store the waste will fail in unforeseen ways. This is most likely to occur as a result of an unforeseen design 'flaw' (perhaps early embrittlement from the constant radiation) or from a natural disaster which the canisters were not designed to withstand (like strong tectonic shifting, asteroid impact, etc.). Engineers are tasked with designing containers that can withstand as much of the foreseeable danger as can reasonably be expected; that is, they attempt to minimize the potential for harm that might arise in a variety of possible accident scenarios. But attempting to minimize foreseeable harm does not eliminate the possibility of harm; there is an inherent level of uncertainty about the long-term behaviour of our technical solutions. Secondly, we are still in the early stages of our understanding about the long-term health and environmental effects of radiation. For the IAEA, it is this scientific and technical uncertainty that is at the root of our ethical problems: "Most of the concerns of an ethical nature in radioactive waste management are the consequence of a partial uncertainty about the long term health and environmental effects of the wastes" (IAEA, 1992, 186).

There is also technical uncertainty about the effectiveness of long-term disposal solutions. While no quantitative data about projected radiation doses from a radioactive waste facility in Canada have yet been made public, there is some worrying data from the U.S. that reflects relevantly on what we can expect from our own models. For more than thirty years the U.S. has been studying the suitability of Yucca Mountain, in Nevada, for the storage of its commercially generated nuclear fuel waste. Unfortunately, despite having spent nearly $30 billion on the site, community opposition may ultimately reject it, thereby forcing the government to seek an alternative waste solution. However, regardless of the public opposition, significant scientific uncertainty remains regarding the models used to estimate predicted dose exposures. According to the IAEA, the "[U.S.] government's own Yucca Mountain studies show its projected radiation doses have uncertainties between 8 and 12 orders of magnitude. This means projected Yucca radiation exposures to the public could be a trillion times too low or too high. Yet if doses were only 29 times higher than the distant-future limit, they could immediately kill human embryos. Doses only 750 times higher could immediately kill half the adults exposed" (Shrader-Frechette, 2005). People cannot reasonably judge the acceptability of a site with such inherent uncertainty about likelihood of radiation dose exposure.

Yucca Mountain is designed for commercial nuclear fuel waste, but the U.S. also has programmes in place for storing its transuranic waste from nuclear weapons production — mostly plutonium. To store non-commercial (i.e. military) waste, the government built the Waste Isolation Pilot Plant in the 1980s, about 40 kilometers south of Carlsbad, New Mexico. Unfortunately, on 23 October 2008 the New Mexico Environment Department (NMED)

> . . . approved a permit change to the U. S. Department of Energy's (DOE) Waste Isolation Pilot Plant (WIPP), which demonstrates that 15 WIPP site locations have been compliant with environmental protection requirements. The permit change eliminates continued sampling and analysis at these locations.[3]

They made this claim after observing that "sampling data, collected by DOE over a 10-year period from the 15 locations, indicated that the areas posed no risk to human

[3] <http://www.wipp.energy.gov/pr/2008/Permit_Change_10-23-08.pdf>.

health or the environment" (ibid.). Recall that plutonium has a half-life of 24,000 years, so it is important that any solution to managing this dangerous and potentially lethal carcinogen be secured for a very long time. It is quite unreasonable to think that a 10-year sampling study is sufficient time to judge that a waste site will be environmentally secure for thousands of years.[4] By not continuing with the monitoring we will also be left with further uncertainty both about the site's effectiveness and waste transportation in the environment.

In addition to technical uncertainties about the effectiveness of a storage solution, there is scientific uncertainty about the effects that radiation will have on a population if an accident occurs. The International Atomic Energy Agency's 20th Anniversary special report on the Chernobyl disaster makes this abundantly evident:

> It is impossible to assess reliably, with any precision, the numbers of fatal cancers caused by radiation exposure due to the Chernobyl accident — or indeed the impact of the stress and anxiety induced by the accident and the response to it. Small differences in the assumptions concerning radiation risks can lead to large differences in the predicted health consequences, which are therefore highly uncertain. . . . The projections indicate that, among the most exposed populations (liquidators, evacuees and residents of the so-called 'strict control zones'), total cancer mortality might increase by up to a few per cent owing to Chernobyl-related radiation exposure. Such an increase could mean eventually up to several thousand fatal cancers in addition to perhaps one hundred thousand cancer deaths expected in these populations from all other causes. An increase of this magnitude would be very difficult to detect, even with very careful long term epidemiological studies" (IAEA: The Chernobyl Forum 2003-2005.)[5]

Technical and scientific uncertainty is not the only limiting factor to predicting

[4] On 21 November 2008 the WIPP project announced that they were commencing with several upgrades to the facility. If just one month prior they claimed that the site is perfectly safe, one has to wonder why the upgrades are necessary.

[5] This document is available from the International Atomic Energy Agency: <http://www.iaea.org/Publications/Booklets/Chernobyl/chernobyl.pdf>.

whether a storage solution will always be safe. Political, social, or individual uncertainty poses another significant problem since the waste will remain hazardous for times longer than any nation has ever remained politically stable and coherent. The philosopher Edith Brown-Weiss states the problem clearly:

> Foremost is that the safety of retrievable disposal depends upon a stable political and institutional environment which will continue to be concerned about the disposal site and to act responsibly in monitoring it and correcting deficiencies. Moreover, maintenance of the facility means greater exposure of workers to ionizing radiation, increased record-keeping burdens, and greater risks of inadvertent entry by people to the site, since access to it must be maintained (Weiss, 1988, 175).

Stable political institutions are not the norm. It is quite possible, over the time-frame needed, that nuclear nations will undergo an armed military overthrow of the government by another country, or an internal coup d'état. Under these circumstances the new regime could have access to the waste and use it for its own (perhaps nefarious) purposes, like extracting the fissile material to build a nuclear bomb; or it might aerosolize the waste over an enemy country or domestic population (a tactic which can cause widespread panic, given our fear of radioactive substances). Similarly, a terrorist organization might try to steal nuclear material for use in a 'dirty bomb' or other nuclear weapon. This is already an issue of considerable concern and speculation in Russia, especially after the dissolution of the Soviet Union.

Once the radioactive material has been created we can only *attempt to prevent* it from harming humans, the environment, or to keep it from getting into the hands of those who would wish to use its harmful effects to inflict injury on others; we can never eliminate the waste. Unfortunately, there are no physical means — either through chemical, temperature, or pressure — of speeding the decay process so that the waste becomes less harmful in a shorter period of time. This is a telling fact which puts pressure on those seeking to declare a storage option ethically good.

5.1.1 Possibility of Failure

Is the possibility that an accident *may* happen, and inflict harm on future people, sufficient reason to forgo the harmful activity in the first place? Such an objection, based on mere possibility alone, would be unreasonable. We could state this objection conditionally: If X might cause harm, then X is not permissible. The 'X' is any activity, such as generating or storing nuclear waste. But everything has the potential to cause harm, so nothing would be permissible. Rather, we need to analyze the two antecedent terms — *might* and *harm* — and stipulate the conditions under which we assent to its permissibility or impermissibility. And here lies the crux of our present concern: what is the *probability* of an accident, and what is the actual *harm* that could result if the accident occurs? The utilitarian would likely reply: When we have given those terms proper values for various scenarios, we will be in a position to weigh the likelihood of harm against the benefits and come to a determination about the permissibility of the action, which in this case is the permissibility or impermissibility of a given long-term storage option. Were it only that easy. The likelihood of an event is confounded by inherent technical and political uncertainties. We are not, regrettably, well-endowed with omniscience. The only certainty is that if we don't do anything to guard the waste from the biosphere, then the waste *will* cause harm; and this is something that most rational agents would agree is a bad thing. How bad? The answer is contentious, especially since many of the harms which arise from radioactive material do not arise for many years or even generations; nowhere is this difficulty more apparent than in modeling radiation-induced cancer rates or germ-line mutations, as we saw in section 4.3.

Unlike almost every other industry, reliability in the nuclear case is paramount, since accidents can be utterly disastrous. Consider the following scenario. When nuclear fuel is removed from the reactor it is about one million times more radioactive than when it first went into the reactor, and must be cooled by water for approximately ten years before it can be moved into actively air-cooled concrete casks. Suppose, however, that during the initial ten years the cooling pond for spent fuel loses enough water to expose some of the fuel to air. The heat would cause the fuel to literally catch fire, and the resulting gamma radiation "would be so intense — 10,000 rems at the edge of the pools and hundreds of rems in certain other areas — [that] the lethal dose would be incurred in less than one hour. This would prevent any efforts by staff to intervene or to contain the situation" (Caldicott, 2006, 103). Furthermore, there is currently no emergency back-up system for these spent fuel bays. So, unlike other accidents (like a coal or oil spill), workers cannot simply 'clean-up' the site and remove the waste because the radioactive material is so intense that workers could only spend a few minutes in the vicinity before they exceeded their yearly acceptable radiation doses. We would thus require hundreds if not thousands of people to clean up the material in short shifts, and everyone involved is at increased risk of cancer. People not directly involved with the production of nuclear energy are also put at significant risk. According to an NRC report, "a fire at a spent fuel pool could produce between 54,000 to 143,000 cancer deaths and would render 2000 to 70,000 square kilometers of agricultural land uninhabitable. In addition, $117 to $566 billion would need to be spent evacuating hundreds of thousands of people from contaminated areas." And "if just 10% of the cooling pool cesium 137 were released by fire, the area contaminated would be five to nine times larger than the area affected to a similar degree by Chernobyl. If 100% were released, the contamination would affect an area about seventy times larger than that of Chernobyl" (Caldicott, 2006, 103). Though this data pertains specifically to the U.S., Canada's spent fuel bays are essentially the same, and so we face this same worrisome problem.

The situation that I just described is not farfetched. Accidents have happened, and we have every reason to believe that accidents will occur in the future. In 1957 a nuclear waste accident in the closed Soviet city of Chelyabinsk-65 (now known as Mayak) killed 200 people and exposed at least 200,000 more individuals to cancer-inducing radiation, especially radioactive strontium-90 (Medvedev, 1979).[6] The accident occurred when the cooling system for a tank with several tons of dissolved

[6] The number of people exposed since the accident is likely closer to 500,000 since the radiation was dispersed in the air, water, and over the land which is used to feed residents. The total amount of released radiation is estimated to be about 20 million Curies.

nuclear waste failed, which resulted in an explosion estimated at 75 equivalent-tons of TNT (Pomper, 2009). It has been called the worst nuclear accident in history (it killed many more people than Chernobyl), and left 25,000 square kilometers contaminated (Medvedev, 1979; Smith, 1989). Despite this horrific event, the Mayak processing site continues to operate, and has had several more serious accidents with significant amounts of radiation released into the environment; in 2003 it had its license suspended for dumping liquid nuclear waste into the environment, but the condition for further operation was simply to install technology that prevented the violation (Pomper, 2009). No independent data exists for examining the full radiological damage which has resulted from this facility over the past fifty years.

A similar accident-scenario almost occurred at the Sizewell A reactor in Britain as recently as 7 January 2007. A Freedom of Information Act request made by journalist John Large revealed that a contract worker using the laundry room noticed a leak coming from the cooling tank. When the alarm was raised, "40,000 gallons of radioactive fluid had spilled out from a 15ft long crack in a pipe. Some of it reached the North Sea. Although the water level in the tank had dropped by more than a foot, none of the sophisticated alarm systems at the power station on the Suffolk coast had picked up on it. The next scheduled safety patrol was not due for ten hours, by which time the level would have dropped enough to expose the nuclear fuel rods, possibly causing them to overheat [and catch fire]."[7] Disaster was *luckily* but narrowly averted. Had dumb luck not struck, and had an explosion in the waste storage facility occurred, Britain would be a much different place today.

A very serious consideration arises when we think about such catastrophic possibilities: what gives us the *right* to endanger both human lives and the environment for hundreds of generations? The NWMO is aware of this concern, as they state in their Ethical Framework that "Special ethical issues arise with respect to risk assessment in the nuclear industry. For example, might some scenarios be so horrendous that even a slight risk of their occurrence would be morally unacceptable or unacceptable

[7] <http://www.dailymail.co.uk/news/article-1192477/How-trip-laundry-averted-nuclear-disaster.html>.

by Canadians?" (Nash & Dowdeswell, 2005a).

5.1.2 Failure of Safeguards

Our radioactive train, once set in motion by the production of radioactive waste, must continue its journey until all its cargo has naturally decayed over hundreds of centuries. Suppose a group stumbles upon the waste facilities in 300 years, but so many radical events have transpired in the intervening years — just think of everything which has changed in the last 300 years — that all indications that the facility is storing radioactive materials are lost; perhaps aeolian processes will degrade external signage, relevant map records will have been lost or destroyed, and the inhabitants understand neither the language(s) in which we wrote the warnings nor our visible symbols of danger. If our past practises are any indication, the future group would exercise curiosity and explore the constructed facility. Radiation is neither visible to the human eye nor does it emit odour, so without Geiger counters (or some other detector) the wayward explorers will, as future archeologists, unearth a terribly dangerous secret. Only after a marked increase in cancer rates and deaths after a bout of radiation sickness would they begin to understand the dangerous nature of the material they unwittingly excavated. Despite our present efforts to increase the permanence and broad indelibility of the danger signs, this scenario is always a possibility; our record-keeping and warning labels can fail, and they can fail in the most pedestrian of ways — someone might paint over the signs with graffiti or cover the warning in dark tape; both of these scenarios have already occurred, among other seemingly innocuous activities that compromise the integrity of the warning systems in remarkably simple ways.[8]

[8] IRID (Ionising Radiations Incident Database) reports one such event: "An analytical laboratory decided to dispose of a number of items of laboratory equipment which included a gas chromatograph containing a 370 MBq nickel-63 source. ... The equipment was not clearly labelled as containing radioactive materials and the system for keeping regular records of the source failed" <http://www.irid.org.uk/documents/annex_a7.pdf>. There are also several reported instances where radioactive Tritium — the illumination source of our exit signs — has been sent to landfills because the warning labels were covered in dark tape.

An illustrative example occurred in 1985 in Goiânia, Brazil. A private radiotherapy institute closed shop and vacated its premises but left behind a cesium-137 unit used for cancer treatment (Angelo, 2004). Scavengers later discovered the radiotherapy unit and took it home, unaware of its contents. While disassembling the unit they ruptured the radiation capsule. "As a consequence, the scavengers contaminated themselves, hundreds of other people, and the surrounding city and environment. Four severely exposed people died of acute radiation syndrome, while many others experienced serious radiation-related injuries" (Angelo, 2004). Three hundred people showed cesium-137 contamination, and the event had a significant economic impact on the city. Though the canister was not properly disposed, the example shows that we cannot rely on individuals to understand (for reasons of literacy, sign-permanence, and so on) the dangers that radiation sources pose.[9]

5.2 Informed Consent

> Q7: In accordance with the doctrine of **informed** consent, are those who could be exposed to harm or risk of harm (or other losses or limitations) being **fully consulted** and are they willing to accept what is proposed for them?

The doctrine of informed consent poses one of the greatest challenges to an ethically justified nuclear power program. Informed consent is a common law condition whereby an individual, or group of individuals, gives consent with a full appreciation and understanding of the risks and implications of the proposed action. 'Full appreciation and understanding' is taken to mean that the relevant parties have the best available scientific information, have honest and accurate social and ethical information, and are able to make the decision voluntarily, free from bias or coercion (including both physical and financial coercion). That is, they are in a position to

[9]Many other examples exist. In Port Hope (Canada), for instance, ores from uranium mining were used to build houses and schools. Several years after construction people discovered that the buildings contained very high levels of radioactive radon, and the contaminated buildings had to be rebuilt with uncontaminated material.

be *informed* about the actual costs and benefits associated with the action, which in this case the acceptability of a radioactive waste repository. Informed consent, therefore, is consent which meets these conditions. People alive today can, in principle, give informed consent by taking the time to understand the nuclear issue and decide whether or not the potential risk is worth the benefit. As a society, we have already consented (which is not the same as informed consent) to the use of nuclear power in virtue of the fact that we allowed the industry to start, and in that we allow it to continue to operate.[10] Likewise, a host-community for a nuclear waste repository can collectively agree to the risk after appreciating the nature of the risk involved. Ideally such a decision will be an informed one.

But how can *future* people give informed consent? The NWMO tries to offer an answer to that important question. If a risk is acceptable today then it is assumed that future people will also consent to the risk. Indeed, the OECD believes this "takes intergenerational equity issues into account, notably by applying the same standards of risk in the far future as it does to the present" (OECD & Agency, 1995). This supposedly justifies their recent 2008 claim that: "Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today" (Fleming, 2008, 115). And if it is acceptable today, then it is acceptable in the future. Such an extension of consent is known as proxy- or second-hand consent. There are, however, good reasons for denying this extension of acceptability, as I will show.

[10] Canada is in desperate need of a federal energy policy. See Duncan Hawthorne "Nuclear Energy: Friend or Foe" speech for a nuclear insider's call for such a policy. See <`http://www.cna.ca/english/pdf/Speeches/03April25AMPCO.pdf`>. From the opposition's side, it is important that we collectively decide whether or not nuclear energy should be a vital component of our energy framework; this should perhaps be a matter for a referendum, but unfortunately no such action is as-yet underway.

5.2.1 Second-Party Consent

People alive today are not the only individuals affected by nuclear power. Many of the decisions we make today have multi-generational ramifications, and so we need to make those decisions with an eye toward how our actions will affect our descendants. One way to examine such decisions is to predict the effects that our actions will have and stipulate that "an action is acceptable if we would consent today to accept the predicted risks." According to Kristin Shrader-Frechette: "Ethicists virtually unanimously agree that proxy consent, on behalf of future generations, requires that present generations also would give consent to the same conditions. If that be the case, then current opposition to permanent nuclear waste disposal argues against the claim that future persons would consent to it" (Shrader-Frechette, 2000, 775). In other words, if it is unacceptable for present people, then it is arguably unacceptable for future people as well. Since future generations cannot give direct consent to the activity, we provide proxy-consent for them. This is also known as second-party consent. Does second-party consent justify exposing future generations to the risks of nuclear waste or its storage facilities?[11]

Generation X's consent is necessary for deeming X+1's consent, but in my view, this is *not* a sufficient condition, especially since we are the actor in this case and they are the affected. As I mentioned, in analogous cases, do we say that the actor's consent counts for the consent of the affected? It clearly does not hold in cases like a doctor-patient relationship. A doctor's consent to have his patient undergo an operation does not mean that the patient has also given consent. In fact, such a situation (apart from some instances of euthanasia) would completely violate a patient's autonomy. Rather, doctor's role is to diagnose the ailment and to offer advice about which treatment will bring the patient back to a healthful state; if the patient provides *consent* to the treatment, then the doctor can begin fulfilling the treatment. Analogously, the diagnosis in our nuclear case is that the health and lives of both present and future

[11]See (Shrader-Frechette, 2002b) for a good discussion of this issue, especially Chapter 5: "Equity and Duties to Future Generations: The Case of Yucca Mountain." I draw extensively, though not entirely, from her exposition for this section.

people are threatened if we allow the nuclear waste to escape into the environment; in other words, it threatens our health if appropriate measures are not taken. The key focal point is *if we allow* it to leak, or otherwise fail to secure it. Thus, the treatment is initially preventative; storing nuclear waste in secure canisters and burying it in the Canadian Shield is a preventative measure. But, as doctors in this analogy, we can only offer our advice that such a measure is the 'best' solution given the circumstances. The patient — i.e., future people — must still consent to that preventative measure, especially since the health-risk is the product of human actions, and not simply an accident of nature. But since they cannot offer consent, any treatment (preventive or otherwise) must be imposed upon them, and this has all the classic hallmarks of coercion.

During the early debates in 1990s on nuclear energy it was often argued that "we are only required to do the best we can in this generation, and that future generations would agree that we did our duty by them, even if we failed" (Dr. Peter Timmerman, personal communication). I think that this reasoning might be acceptable if we had no other options, and our survival depended on nuclear-generated electricity. In such a case we may "only be required" to do our best at containing the risk. But we have alternative options — including not using any nuclear-generated electricity — and so the problem of risking the lives of future people in the event of containment failure can be avoided. Our duty, therefore, is stricter. Because we "could have done otherwise," and chosen a safer route for generating electricity, failure of the containment structure would constitute a dereliction of duty.

There are several other ways in which second-party consent does not constitute justification. First, "a majority of persons across time probably [would not] support permanent radwaste disposal" (Shrader-Frechette, 2002b, 106). Second, this is a policy adopted by a minority of individuals. Only a few individuals are making the decision today, and yet the majority of the people affected by the decision are either not party to the discussion or not yet born. Third, we can tolerate the risks of permanent radwaste disposal only if the burden of injustice is evenly distributed. According to John Rawls:

> when they adopt the majority principle the parties agree to put up with unjust laws only on certain conditions. Roughly speaking, in the long run the burden of injustice should be more or less evenly distributed over different groups in the society, and the hardship of unjust policies should not weigh too heavily in any particular case.[12]

This condition is not met in the nuclear waste case. Indeed, "one of the apparently necessary conditions for affirming the second-party consent of future persons — that the consent is to a scheme that evenly distributes societal risks, costs, and benefits — cannot be met" (Shrader-Frechette, 2002b, 107). Future people will bear some of the societal costs, though how much cannot yet be determined. And, as we will see shortly, taxpayers not directly benefiting from nuclear power also bear a large portion of the burden unwillingly, and so there is some fundamental inequity even among presently existing people.

Furthermore, the problem of informed consent is made quite difficult, if not impossible, with so much technical and political uncertainty. Shrader-Frechette expresses the issue well:

> One cannot consent to a situation when so many vital safety factors regarding it are uncertain. Hence even if one assumes that second-party consent is legitimate in the case of geological disposal, the scientific uncertainty about the relevant repository risks appears to jeopardize the conditions necessary for disclosure and therefore the free informed consent of future generations. Likewise, if uncertainty blocks conditions necessary for disclosure, it probably also blocks conditions necessary for understanding the situation to which one must give or withhold consent. (Shrader-Frechette, 2002a, 109).

It is therefore incumbent upon the NWMO and the nuclear industry to minimize uncertainty through both scientific investigations and publicly disclosing all information, including information about the extent of uncertainty that still exists in the existing

[12] Cited in (Shrader-Frechette, 2002b, 107); Rawls' *A Theory of Justice*, p. 355.

models and our available knowledge. This requirement is suggested by their ethical question Q4. Unfortunately, according the United Church of Canada and members of the Roundtable on Ethics, this requirement has not yet been met. By way of brief background information, during the Roundtable on Ethics discussions, and throughout much of the nuclear power debate, the United Church of Canada has taken an active role in helping to develop an ethical framework, providing both guidance for the proposal and important critiques of the principles (Wilson, 2000). Their involvement stems from the realization that as members of this society they are partly responsible for the generation of nuclear power and must therefore assist in its ethical solution. In order for any group, like the United Church or other Canadians, to provide a meaningful positive contribution to the development of an ethical framework the basic assumptions and groundwork upon which the framework will be built needs to be made explicit. Unfortunately, lack of clarity and conceptual rigour regarding the basic ethical assumptions pervades the NWMO's document and final study, and concerns about this issue were raised by members of the United Church in the 18 October 2004 Advisory Council meeting of the Roundtable on Ethics:

1. The values that one brings to assessing the management options will influence the assessment of the options. It is important for values to be made explicit in any assessment. There is insufficient transparency concerning how the values have been embedded in the NWMO's framework and how they will be applied.
2. An ethical process must bring forward all relevant information to the study. In this regard, how narrowly or broadly NWMO bounds the issue will determine in part how ethical the recommendation is. For public trust, it is important to frame the issue of waste management in a way that takes into account implications for the future of nuclear power. The Church sees these issues as inseparable. A full and open debate on the life cycle of nuclear energy is required. Better yet, it would be ideal to hold a referendum on whether or not Canadians want to include nuclear power in their energy future; for a matter as important nuclear power this seems like the only reasonable and inclusive tactic.

3. A better documentation of the facts, what is known and unknown, is required. Our state of knowledge is insufficient, there are too many uncertainties.[13]

The United Church and I are in agreement on these points: the degree of uncertainty about the long-term health effects and stability of the redhibitory, the lack of clarity about the ethical requirements of the NWMO's approach to the long-term management of nuclear fuel waste, and the fact that the NWMO's study did not address the management of possible future nuclear waste production, mean that we do not have enough information to make a fully informed decision about the 'best' solution to our radioactive burden. Even if these conditions were met, further serious difficulties remain with the justification of multi-generational (second-party) informed consent, including the variability of radiation standards and the important condition of voluntary assumption of risk.

5.2.2 Radiation Standards

Another obvious place where uncertainty impedes the possibility of fully informed consent is in the case of radiation standards. It is presumptuous for us to assume that we presently have full information about the complete health effects of ionizing radiation, and that our current standards will still be acceptable to people in the future. Radiation standards might change as we come to a better understanding of the effects that radiation has on our cells and genes. Would future generations, given a more complete understanding of radiation and its health effects, still accept the risk? There is reason to think that they would not. As we saw in section 4.3 (Radiological Protection), *no* amount of radiation exposure is safe, and nuclear power adds to the risk of radiation exposure already present in the earth's natural environment (the so-called 'natural background radiation' found in our water sources and soils, among other places). This is a significant problem given that the background radiation levels

[13]See the NWMO Advisory council meeting: 18 October 2004.

are deemed responsible for a large number of fatal cancers every year. "According to the United Nations Scientific Committee on Effects of Ionizing Radiation (UNSCEAR), the International Atomic Energy Agency (IAEA), and other scientific groups, natural-background radiation causes about 3 percent of fatal cancers — roughly 18,000 annual U.S. deaths" (Shrader-Frechette, 2005, 3). Are we justified in adding to that already dangerous level? How much more is acceptable?

Genuine acceptability is further limited by the fact that radiation standards have changed many times.

> The International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurement have had standards for public and worker protection from radiation for more than 45 years. The ICRP standards have changed several times over the past 45 years to reflect new data and understanding of hazards from plutonium. In addition, the current philosophy of radiation protection is to keep radiation exposures as low as is reasonably achievable.[14]

An established, unvarying standard ought to be met before we can pursue proxy-consent for future generations. There is no reason to assume that we currently understand all the health effects of radiation, and we ought to assume that our standards will continue to change over time. Moreover, the "As low as reasonably achievable" (ALARA) condition may still be a risk above some future standard; the fact that some risk is low (or lower than another risk), does not mean that it is below the threshold of harm. If future generations were to accept a nuclear waste proposal, full information about actual risks of harm involved would have to be established — the main reason that present people consent to nuclear waste under this condition of uncertainty is owed to the fact that present people receive the benefit from nuclear energy, whereas future people will only receive a burden and none, or very little, of the benefit. On any reasonable cost-benefit approach the answer will clearly be *no*, nuclear waste is not an acceptable burden.

[14] <http://www.cdphe.state.co.us/rf/plutoniu.htm>.

5.2.3 Voluntariness

In addition to the uncertainty about the full radiological health effects and uncertainty about the appropriateness of our radiation standards over time, the presumption that an acceptable risk today is always acceptable into the future must be challenged further. When we make a decision about, say, driving an automobile, we can voluntarily accept the risk of having an accident on the road. The same is true of accepting a hazardous job — like working on an Oil-Rig or nuclear power facility — but in such cases we may rightly ask for greater financial remuneration to offset the increased risk. The key point, however, is that we accept such risks *voluntarily*.

Future people, by definition, do not exist presently and so they cannot voluntarily *consent* to accepting the burden of nuclear waste. Thus we are ultimately sending the waste to them without their permission, and they do not even have the option of sending it back. Is it ethically acceptable to impose the burden of nuclear waste on individuals who cannot consent to accepting the risk, and most likely would not consent if the option were available? For its part the NWMO states that they will impose this risk 'fairly.' But we must ask: What does that mean? How can we fairly impose a risk of harm upon a non-voluntary population? This is a key question in the debate.

5.2.4 Revising the Informed Consent Condition

Let us return briefly to the initial requirement of seeking informed consent from *all of the relevant parties.* Future people are, given the long-term nature of the hazard, clearly relevant parties. But, the brute fact of the matter is that future people do not exist and therefore cannot offer *any* type of consent; therefore, as formulated, the NWMO's informed consent requirement is strictly not satisfiable, and must eliminated. We will impose a burden on future people, but it is a burden for which they cannot consent. Many of our actions on this planet, however, have multi-generational ramifications, and so some form of constraint is often presupposed or explicitly implemented when developing policies about how to manage multi-generational risk. For example, we manage household garbage by emplacing it in landfills and not (ideally) in the river-streams or lakes. The justification for this procedure is simply that present people need clean water, desire clean rivers and lakes, and do not want to ingest household pollutants, so it is in our collective best interest to isolate the waste. And, if it is a good enough solution for present people, then it is a good enough solution for future people too. Or, to phrase it in the nuclear context, if the present generation has given fully informed consent for a given nuclear fuel waste repository, then their consent implies that future generations will also consent to the repository (so long as the repository is built with the presumption that the repository will contain the waste for a reasonable amount of time and be resistant to foreseeable calamities). This type of reasoning undergirds proxy- or second-party consent, and it the basis used by the NWMO's to putatively satisfy its obligations to future people. But, as I have shown, even second-party consent fails in several ways in the nuclear case. Some of those reasons include: (a) a majority of people across time would not consent to the production of nuclear fuel waste; (b) too many vital safety factors are uncertain to meet a reasonable standard of what it mean to be informed; (c) radiation standards are not static, and future research might demonstrate that exposure to the currently acceptable levels of radiation is more harmful than presently believed; and (d) the condition of accepting a risk voluntarily after a consideration of the costs and benefits, rather than having the imposed, is not met — future people can never voluntarily choose to accept or not accept the radioactive burden.

5.3 Respecting Life and Nature

> Q8. Do NWMO's recommendations reflect **respect for life**, whatever form it takes, whenever it occurs, and whenever it exists (now and into the foreseeable future?) In particular, are NWMO's recommended solutions likely to protect human beings, including future generations, other life forms and the biosphere as a whole into the indefinite future?

One of the overarching ethical themes in the NWMO's ethical framework is that, in Canada, we should give "special attention to aboriginal communities, as is mandated by the governing legislation" (Nash & Dowdeswell, 2005a, 367). 'Special attention' might mean two things in this context: that any decision regarding a waste repository should give special weight (voting rights perhaps) to Aboriginal peoples, or that the proposed solution should incorporate some of the ethical principles of Aboriginal peoples. The Final Study (2005) is unclear on this matter, though at times it appears to support both options. Let us consider the second option in this section.

The clause that we should "respect life" arose from discussions with Aboriginal communities in Canada. They have particular world-views and which need to be respected and incorporated into the management solution. Though there are no invariant epistemological, ethical or ontological perspectives (a common world-view *per se*) among *all* Aboriginals in Canada, their viewpoints do converge on some fundamental underlying values. Their perspectives were highlighted during the Aboriginal Traditional Workshops held in September 2003 for the NWMO. According to Joanne Barnaby, Aboriginal peoples in Canada share "an understanding that there is life in everything in nature; there is no such thing as an inanimate object."[15] This spiritual animism is coupled with further traditional principles of: "Respect, Honour, Conservation, Sharing with Reciprocity (giving to each other and to Mother Earth in conscious recognition of the gifts received from her and our stewardship responsibilities." She also calls on the NWMO to take the entire fuel cycle into consideration, everything from mining to managing the waste.[16] A further issue might be the location of a dump site closer to the aboriginal rural reserves than to Canadian metro areas, thus giving Aboriginals a greater stake in the decisions.

Further reference to aboriginal concerns can be found in a biosphere modeling report for nuclear fuel waste management by R. Zach of AECL. He states that "Aboriginals closely identify with the environment with [sic] its plants and animals on which they still depend for their survival, and their physical and spiritual well-being. As a result

[15] NWMO Advisory council meeting: October 18th, 2004.
[16] Canada is still without a coherent ethical framework for the entire nuclear fuel cycle.

of this, aboriginals have a unique relationship with the environment and have also accumulated unique knowledge regarding it" (Zach, 1997a, 27). From this it appears that we have an obligation to respect their ties to the environment and consult them on their accumulated knowledge in the hopes that we could develop a respectful solution to the management of nuclear fuel waste.

But the Aboriginal perspective is not given much importance in developing a solution, despite rhetoric to the contrary. According to the meeting minutes of the 17 January 2004 meeting, members of the Roundtable admitted that "[We] cannot see how aboriginal ethics can be applied to finding a waste solution since if these ethics had been applied earlier we never would have embarked on the nuclear energy path which has created this situation in the first place. One cannot possibly guarantee anything for the length of time this material remains hazardous."[17] Elder Billy Two Rivers echoed this sentiment several months later at the 17 November 2004 meeting: "the issue is one for which the Aboriginal perspective cannot be used because Aboriginal people would not have taken a path to produce this waste in the first place." Thus, if we were to have genuinely taken the perspectives of Aboriginal peoples seriously in the beginning, there would be no nuclear industry in Canada today. While we cannot undo history, we can reflect upon what has passed and orient our policies toward a more ethically sound approach for the future. The Roundtable has taken this idea to heart by agreeing on the minimal ethical requirements regarding the storage of old waste and the conditions necessary for the production of new waste:

> Since "something" has to be done with the [earlier] wastes, a least-bad solution is morally acceptable if that is the best there is. Whereas for creation of new wastes to be morally acceptable, there must be not just a least-bad management solution, there must be a genuinely good solution.[18]

The message is clear. Despite the fact that the NWMO is not mandated to consider the future of nuclear energy, it cannot be separated from the ethical framework. "It

[17] Roundtable on Ethics, 17 January 2004.
[18] Roundtable minutes 17 November 2004.

is very important ethically that NWMO address the future of nuclear energy. Whether it is written in the mandate is really of no consequence."[19] Thus, while the best condition that we can hope for regarding our current waste management requirements is a 'least-bad' solution, generating more nuclear fuel waste requires an ethically acceptable framework. For Aborginal communities, generating more nuclear waste is not consistent with the idea of respecting nature, given the type of waste and duration of the potential harm involved.

5.3.1 Seven Generations

One of the core recommendations from several panels (Seaborn, etc) requires whomever is ultimately responsible for the storage of nuclear waste to take the interests of aboriginal people into account. This requirement is often explicitly stated in the Final Study document (Nash & Dowdeswell, 2005a). To abide by this recommendation, the NWMO has nominally adopted the putatively Aboriginal seven generations principle. The *Seven Generations Principle* states that 'we must respect the interests of our descendants who will be born seven generations from now into account when deciding a given course of action.'[20] Seven generations for humans is about 150 years. Debate about implementing this principle rests upon the interpretation of what it means to 'respect the interests of future people.' But people have a lot of interests, and we can reasonably assume that future people will also have a variety of interests, so there is some ambiguity about which interests ought to be considered relevant to the seven generations principle. For instance, it is quite apparent that future people will have an interest in basic subsistence requirements like clean air, potable water, and arable land. But they may also have an interest in fast computers, gasoline-powered cars or

[19] Roundtable minutes 17 November 2004.

[20] The original formulation likely comes from the *Gayanashagowa* (the Great Law of Peace), the oral constitution of the Iroquois people. In section 28 it reads: "”Look and listen for the welfare of the whole people, and have always in view not only the present, but also the coming generations, even those whose faces are yet beneath the surface of the ground the unborn of the future Nation." The modern interpretation is the seven generations principle. <`http://www.iroquoisdemocracy.pdx.edu/html/greatlaw.html`>.

planes, virgin Boreal forests, and a robust tuna-fishing industry. Should we 'respect' all of those interests equally and ensure that future people have complete access to all of the options that we presently enjoy? Or, should we only be required to maintain a certain level of quality with respect to the fundamental interests? And what, exactly, are those fundamental interests?

Rather than enter into an exercise of cataloguing the variety of configurations of potential interests, I shall assume that, at minimum, respecting the interests of future people involves minimizing the potential harm posed by our existing nuclear waste so that we ensure, to the best of our abilities, that access to clean air, potable water, and arable land — three fundamental interests that all people share — are not compromised. This is consistent with the NWMO's dictum that it ought to 'minimize harm' to present and future people. Minimizing harm, however, is only a 'least-bad' solution for existing waste, and the threshold for minimum (acceptable) harm is dependent on a cost-benefit analysis. An aboriginal person will agree that a least-bad solution is the best that we can achieve for managing existing waste (as even the least-bad option threatens the interests of future generations), but such a solution is not thereby condoned for generating new waste through the commissioning and operation of new nuclear reactors. Her reasoning is as follows: according to the seven generations principle, an action which may affect future people is morally acceptable if the action is deemed unlikely to cause harm to any person within the next seven generations; the action is immoral if it may lead to harming future people. Does nuclear waste violate this principle? If there is an accident at the nuclear waste facility then there is the potential that carcinogenic radiation could contaminate a region's drinking water, arable land, and both nearby fauna and flora. The effects of an accident, moreover, will perdure for centuries, thereby compromising the basic interests of future people. In addition to compromising the ability of future people to meet their fundamental needs, an aboriginal may rightly claim that generating more nuclear waste shows a callous disrespect for nature; our nuclear waste imposes an increased radioactive burden, beyond the background radiation levels, upon Mother Earth and all of her inhabitants, and not just humans. Unless we can guarantee that our nuclear waste will remain isolated and secure for the entire duration of its harmful existence, we cannot say that the waste will harm neither nature nor the interests of future people. For these reasons, the seven generations principle is violated when we continue to use nuclear power.

5.4 Precautionary Principle

> Q6. Is NWMO conducting itself in accord with the **precautionary approach**, which first seeks to **avoid harm and risk of harm** and then, if harm or risk of harm is unavoidable, places the burden of proving that the harm or risk is ethically justified on those making the decision to impose it?

The precautionary principle, number Q6 in the NWMO's ethical framework, is a decision-making procedure or heuristic that bids us to *not* act recklessly with the application and development of new technologies that may pose a danger to humans or the environment, both now and in the foreseeable future. It is often expressed colloquially in well-trodden aphorisms like 'Better safe than sorry,' 'An ounce of prevention is worth a pound of cure,' and the legal dictum 'Innocent until proven guilty.' In government policies around the world there are no less than fourteen different instantiations of the principle, often with varying degrees of risk-averseness and criteria (Foster et al., 2000).

We find versions of this principle in several international documents. A strong formulation, found in the World Charter for Nature (1982), states that "where potential adverse effects are not fully understood the activity should not proceed." Taken literally we should not develop any new technology (Foster et al., 2000). Clearly this version is too strict for practical use. The potential for harm is not reason enough to prevent an action. Every action or development has the potential to cause damage or harm. A crucial aspect of the principle must therefore be a guideline for determining a threshold for how much risk, given the potential harm or adverse effects, we are willing to accept for the beneficial payout of the action.

Perhaps the most famous formulation of the principle is found in the 1992 Rio Declaration of the U.N. Conference on Environment and Development:

> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.[21]

Yet another formulation, the last that I will present here, is known as the Wingspread Principle (which arose out of the Wingspread conference held by the Science and Environmental Health Network in 1998):

> When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically (Raffensperger and Tickner 1999: 8).[22]

Each of these formulations share some common threads, including the concepts of risk, harm, and a threshold of acceptability; they are all difficult to assess and almost always the locus of debate in disputes about applicability of the precautionary principle in any of its forms.

Risk, as we've seen, is the probability (or potential) that something undesirable may occur (Martin & Schinzinger, 1996, 131). More elaborately, risk is a function between potential adverse effects (harm) and viable safety measures inversely proportional to our state of knowledge of the system. Each variable is somewhat interdependent; the more knowledge we have about a system, the more information (and accuracy) we can determine about the potential harm, and the more effective steps we can take to implement proper safety mechanisms to lower risk.

[21] Taken from (Manson, 2002).
[22] From (Turner & Hartzell, 2004).

Harm is the adverse consequence that an action induces in a given context or situation. To cause harm to someone or the environment is thus to cause damage or bring about a change for the worse in the system. It has two important meanings here: it can mean (a) the risk of physical damage; (b) actual physical damage or a worsening of one's state. In the literature regarding nuclear energy both versions are very important. Meaning (a) holds the greatest amount of moral force since it is the threat of great radioactive damage that keeps us concerned about the nuclear industry; where accidents have happened, such events only serve to bolster the anti-nuclear position. Actual physical harm includes any radiation damage to our bodies, like cancers and germ-line defects, and of course radiation sickness or death. Receiving a radiation dosage greater than the permitted limit of exposure could also be considered a physical harm. There is also the possibility of economic harm if the costs of cleaning up an accident (or even storing waste for the first time) is borne by the populace or people not directly involved in the production of nuclear waste. Cost-overruns (which are common in the industry) are the most likely potential for economic harm, but I will not pursue this problem here any further.

Since any activity poses a foreseeable risk of harm, the risk should satisfy a threshold of social acceptability. The *threshold problem* has been expressed as follows: "How much scientific evidence do we need concerning the likelihood that activity A will have a consequence E, and that E will be harmful, before we judge that A poses a threat of harm?" (Turner & Hartzell, 2004, 456). Implicit here is the view that 'threat of harm' is synonymous with 'unacceptable.' Thus it is a normative judgement that the act in question is too risky to proceed. Alternatively phrased, the threshold is the limit of acceptable risk. It is a value judgement that groups or societies must determine as there is no clear scientific answer; the science can only tell us about the danger, not whether we are willing to accept the risk of such danger. Setting it too high — that is, requiring too much caution — can stifle progress and economic growth. Setting it too low, by not requiring enough caution to minimize risk of harm to humans and the environment, is likely to be morally unacceptable, not to mention financially disastrous in the case of an accident.

To judge a risk acceptable is also to judge the locus of that risk as safe. Lawrence has expressed this idea well:

> A thing is safe if, were its risks fully known, those risks would be judged acceptable in light of settled value principles. More fully, a thing is safe (to a certain degree) with respect to a given person or group at a given time if, were they fully aware of its risks and expressing their most settled values, they would judge those risks to be acceptable (to that certain degree).[23]

By 'settled values' is meant something like those things the group or society agrees are highly important. For example, protecting human life. We are prone to be more risk-averse with an activity that threatens such values. One obvious problem with this characterization of safety is that it can only be determined after-the-fact, yet we need to make an assessment of the risks compared to our settled values well in advance of knowing all the relevant information. Whether we can be 'fully aware' of all the risks at any time is an open question.

5.4.1 Core structure of the Precautionary Principle

Neil Manson has attempted to further conceptualize the general core structure common in all formulations of the precautionary principle. For him, every version shares a three-part structure: a damage condition, a knowledge condition, and a suggested remedy (Manson, 2002, 265). According to Turner and Hartzell (2004), the *damage condition* "specifies some foreseeable and harmful effect that some activity might have for the environment or for human health" (Turner & Hartzell, 2004). Manson himself stipulates that it requires that we 'specify the characteristics' of the effect on the environment. I take this to mean that we are expected to know the consequences and damages of our actions, naturally enough. Many of the cases in which the precautionary principle needs to be applied, however, can neither be reliably predicted

[23] Passage taken from (Martin & Schinzinger, 1996, 130).

(foreseen) nor the effects reasonably calculated beforehand. Chernobyl is one obvious example; several moderately severe accidents at Canadian nuclear reactors are another; the effects of genetically modified organism yet another.

His second part is a *knowledge condition* which specifies "the status of knowledge regarding the causal connections between" an action and its effects (Manson, 2002, 265). This includes the effects radiation induces after a certain amount of time and dosage. Since studying this causal relation can only be done (ethically) after an accident, and even then the data has always been incomplete (witness the Chernobyl reports), satisfying the knowledge condition in this case in a predictable manner has yet to be done; at best our experiments broadly approximate the relationship in the field. Finally, the third condition specifies a *remedy* that decision makers can adopt to rectify the situation. Manson's use of the term 'remedy' (actually, he uses "e-remedy") is unfortunate as it suggests a remedial measure to be undertaken, and yet by his criteria it can include measures taken to prohibit the potentially adverse action in the first place. Each part and their conditions are listed on figure 5.1.

Intuitively Manson has captured some element or core notion undergirding the precautionary principle. For any technology or action to warrant caution it must foreseeably pose a risk of harm to humans or the environment. [Ekeli (2004) makes this foreseeability condition central to holding individuals responsible for their actions which may harm future generations]. That is, the potential damage must warrant caution, and in order for us to understand this risk we must study and model its predicted effects. The result of this assessment also relies heavily on our understanding (knowledge) of the causal links between, for example, an accident and its environmental and human effects. Such knowledge varies in degree of accuracy, largely in proportion with the amount of time and research we have had to study the relevant phenomenon; the effects of different doses of radiation on humans and the resultant risk of cancer is one example. The remedies are simply guidelines for how we will intervene in the process, often through banning a practice or technology, or mitigating the damage in various ways; I will return to this point shortly.

Three Part Structure of the Precauionary Principle		
SUGGESTED DAMAGE CONDITIONS	SUGGESTED KNOWLEDGE CONDITIONS	SUGGESTED E-REMEDIES
1. Serious	1. Possible	1. Ban or otherwise prevent the e-activity
2. Harmful	2. Suspected	2. Put a moratorium on the e-activity
3. Catastrophic	3. Indicated by a precedent	3. Postpone the e-activity
4. Irreversible	4. Reasonable to think	4. Encourage research alternatives to the e-activity
5. Such as to destroy something irreplaceable	5. Not proven with certainty that it is not the case	5. Try to reduce uncertainty about the causal relationship between the e-activity and the e-effect
6. Such as to reduce or eliminate biodiversity	6. Not proven beyond a shadow of a doubt that it is not the case	6. Search for ways to diminish the consequences of the e-effect
7. Such as to violate the rights of members of future generations	7. Not proven beyond a reasonable doubt that it is not the case	7.

Figure 5.1: Three-part core structure of the precautionary principle (Manson 2002).

Though we ought to welcome any material that opens debate on this matter, Manson's scheme falls far short of being useful. Looking at 'serious' or 'harmful' in the damage category doesn't tell us anything about how serious, or how harmful, an action or technology might be. These general categories are so vague that they will undoubtedly desert the conceptual regiment upon the first call to practical duty. Nevertheless, we can see that his damage condition roughly corresponds to 'actual harm', and his knowledge condition roughly corresponds to the version of 'risk' defined as the probability of an event (E) given some action (A), or P(E/A). From the discussion in the previous section it is clear that we need to be more specific about what we mean by risk, in addition to taking more seriously the idea of potential harm as a vital component in our decision-making process used for determining issues about nuclear energy. Moreover, so much of the literature gives only a qualitative assessment of risk. We need at least some good, transparent quantitative analyses of the risks and potential harm for us to make better decisions in this matter; that is not to say we ought to rely solely on quantitative measures, only that we need a quantitative basis before we can make informed decisions. Once we have assessed (even approximately) the potential damage under various possible scenarios, we can take action to invoke a precautionary measure (or what Manson calls a 'remedy').

The term *precautionary measure* is ambiguous; we must distinguish between abstinence, prevention, mitigation, and amelioration (Turner & Hartzell, 2004, 456). Abstinence, obviously, bids us to restrain from performing some activity, like building nuclear power plants. Prevention is broader, but can include actions that are intended to reduce the probability of an undesired effect, given an activity; for example, installing redundant safety mechanisms in the core to prevent a meltdown. Mitigative measures reduce the amount of harm, of likelihood of harm, but don't actually stop the activity; this is captured by some policy makers' views that 'the solution to pollution is dilution'; burying nuclear waste underground is another example. Ameliorative measures are taken after-the-fact, and often judical and compensatory in nature; for example, paying money to individuals affected by some activity, like excessive radiation exposure or residential school abuse.

Thus, according to the precautionary principle, we should only proceed with an action if the risk (probability) of harm is low and meets the threshold of acceptability. The underlying moral presupposition here is that it is immoral to harm or impose a risk of harm on someone who has not consented (accepted) to be subject to the harmful material (or consented to the risk of harm). Radioactive material, however, poses the danger that it will harm individuals who have not accepted the risk, namely (but not exclusively) future generations. The acceptability of any harm is measured against the amount of benefit that someone bearing the risk will receive. Most often the extra risk passes the threshold of acceptability if financial compensation is offered. Financial compensation, however, will differentially sway individuals depending on their present wealth; poor people are more willing to put themselves at risk in exchange for money than is someone already financially well-off. Alternatively, a repository site could be forced upon a relatively poor community because the depositors know that the community cannot afford to defend itself legally against such actions. In the literature this issue is known by awkward term 'environmental racism,' though I think that 'economic discrimination' is more appropriate — either way, environmental problems are imposed upon the least-well-off people, and this is considered by many scholars to be a fundamental injustice (Cole & Foster, 2001). Calling this practise a fundamental injustice, in my view, purposefully precludes the possibility that such economic incentives (or to put it pessimistically: economic coercion) may help to bring the individuals out of poverty. Why should we deny those people the right to bear an increased risk in return for financial compensation and employment opportunities? Indeed, we shouldn't deny them that opportunity. But the NWMO must make efforts to ensure that *actual* risk and harm involved is made publicly available so that the community can make its decision in a relatively informed manner; this requirement follows directly from the precautionary principles, that the imposed risk must not only be justified, it must be known (and where uncertainty remains, such unknown factors must be openly admitted).

One further concern needs to be raised. The precautionary principle assumes that harm is acceptable if the risk is low and it meets the threshold of acceptability. Even if we assume that a management solution is socially acceptable, the principle that we *minimize harm* still assumes that we are entitled to impose *some* risk of harm on people who have not consented to the risk. If true, then any future deaths or cancers that arise from nuclear activities are *morally acceptable* so long as the risk of radiation dosage does not rise past the level that the present generation has deemed acceptable. For the reasons discussed throughout this chapter such a claim is not evidently justified.

Finally, generating nuclear waste may not be warranted even if the probability of failure is low. Consulting the NWMO's ethical principles again, namely Q9, we find that: "Special ethical issues arise with respect to risk assessment in the nuclear industry. For example, might some scenarios be so horrendous that even a slight risk of their occurrence would be morally unacceptable or unacceptable by Canadians?" Catastrophic failure of a nuclear power plant (or a waste facility) is just such a horrendous scenario, and the highest degree of precaution is warranted.

5.5 Summary

To summarize this chapter then, the NWMO's criteria examined herein either: (a) are themselves vague and unhelpful; or (b) where helpful, the facts show that current practise and proposals for the disposal of nuclear waste fail to meet them. One final criterion remains to be discussed in detail: that of fairness.

Chapter 6

Intergenerational Fairness

Q10: If implemented, would NWMO's recommendations be fair?

> "What are our moral obligations to future generations? Unless a catastrophe occurs people will be alive on earth 500 or 1000 years from today. What claims do they have on us today, if any? Are they morally considerable? Would it be an evil thing if they never come to exist? Who are the "they" we are talking about? If "they" don't exist, how can we be said to have duties to them?" (Pojman, 2001, 278).

Any attempt to safely manage nuclear waste for a time longer than two or three generations presupposes some obligation to distantly future generations. All nuclear nations have already begun such programmes, so the question is not *whether* we have an obligation; we presume that we do. Rather, our ethical problem is specifying the nature of this obligation. The central core of that obligation, for the Nuclear Waste Management Organization, is a matter of fairness. The NWMO makes this explicit: "Given the nature of the hazard, *it is imperative that we consider matters of "equity" or fairness* within the current generation and future generations" (Nash & Dowdeswell, 2005b, emphasis added). Thus, it is incumbent upon the organization to specify how we can distribute the burden of a radioactive waste disposal facility *fairly* across an extensive number of future generations.

Intergenerational equity (or intergenerational justice) is the rubric for theories which specify the nature of fairness or justice between generations. Specifically, intergenerational equity refers to the "relationships of obligation, right, or benevolence that ought to exist between groups of people who are not temporally continuous or to that set of issues which apply to noncontinuous populations, in the same way that intra-generational justice applies to populations that do not spatially overlap" (Kelly, 2001). A generation is, biologically speaking, a group of genetically related organisms constituting a step in the line of descent. However, due to the the length of time each successive step takes for humans (approximately 20-30 years) no sharp boundary can be drawn between when one generation ends and another begins. This is not a critical problem as some temporal imprecision is acceptable. Rather, it is temporal discontinuity that poses the significant problem for intergenerational justice.[1] Temporal discontinuity arises because present people might have obligations to future generations that are not temporally contiguous. (Contiguity is the relation of being very close or connected in space or time.) This raises three fundamental problems for a theory of intergenerational equity:

(1) Can we have obligations to non-existent people?

(2) If so, to whom do we owe such obligations — *all* future people, or *some* subset of that group?

(3) What specifically do those obligations oblige us to do?[2]

The NWMO answers these questions by assuming that we do have obligations to all future people, and that the specific obligation is a matter of treating future people

[1] Kelly (2001) calls the problem 'nontemporal continuity'. I disagree with the terminology and adopt a different approach — the problem is fundamentally temporal but it is the discontinuity of temporal overlap that concerns of intergenerational justice; that is, the obligations of the present people to distantly future generations.

[2] See Golding (1972) for similar concerns.

fairly. Although the NWMO offers no explicit reference about the origins of its dictum to treat future people fairly (contained in its principle Q10), I will argue in this chapter that the NWMO's concept of fairness is based on the version developed by the philosopher John Rawls. That is, any siting procedure and safety measures of a repository should not unduly disadvantage the least-advantaged members of the society or community. Thus, the NWMO claims that it distributes the risk fairly if (a) present users pay for the full cost of disposal, and (b) it 'respects nature and future generations.'[3]

6.1 The NWMO's Fairness Conditions

The NWMO bifurcates the concept of fairness into two broad categories: *procedural* and *substantive*. Figure 6.1 diagrams the various relations among these two categories. We may fairly assume this chart encapsulates their two conceptions of fairness since the NWMO's Roundtable on Ethics made the following remark: "People may ask, 'Did they [the NWMO] understand what fairness actually means?' They can go to the bubble diagrams [in the chart] to judge for themselves."[4] Let us examine the content of that chart.

Procedural fairness defines the decision-making procedures and considerations for the public acceptability of a nuclear waste management solution. The central aspects are public participation and engagement, availability of salient information (risks, effectiveness of management, system performance), and opportunity for the public to influence the decision outcomes meaningfully. Acceptability of an approach requires, in part, an evaluation of any costs and benefits within these constraints. This is a large and daunting task that must be undertaken by all the participants, presumably in a procedurally fair and democratic manner. 'Procedurally fair' in this context means that the decision is made free from unwarranted bias, coercion (financial or

[3]Many thanks to professors Mathieu Doucet, Patricia Marino, Brian Orend for their thoughtful and constructive comments on this section.

[4]Roundtable meeting minutes from 17 November 2004.

Figure A8-1 Fairness Influence Diagram

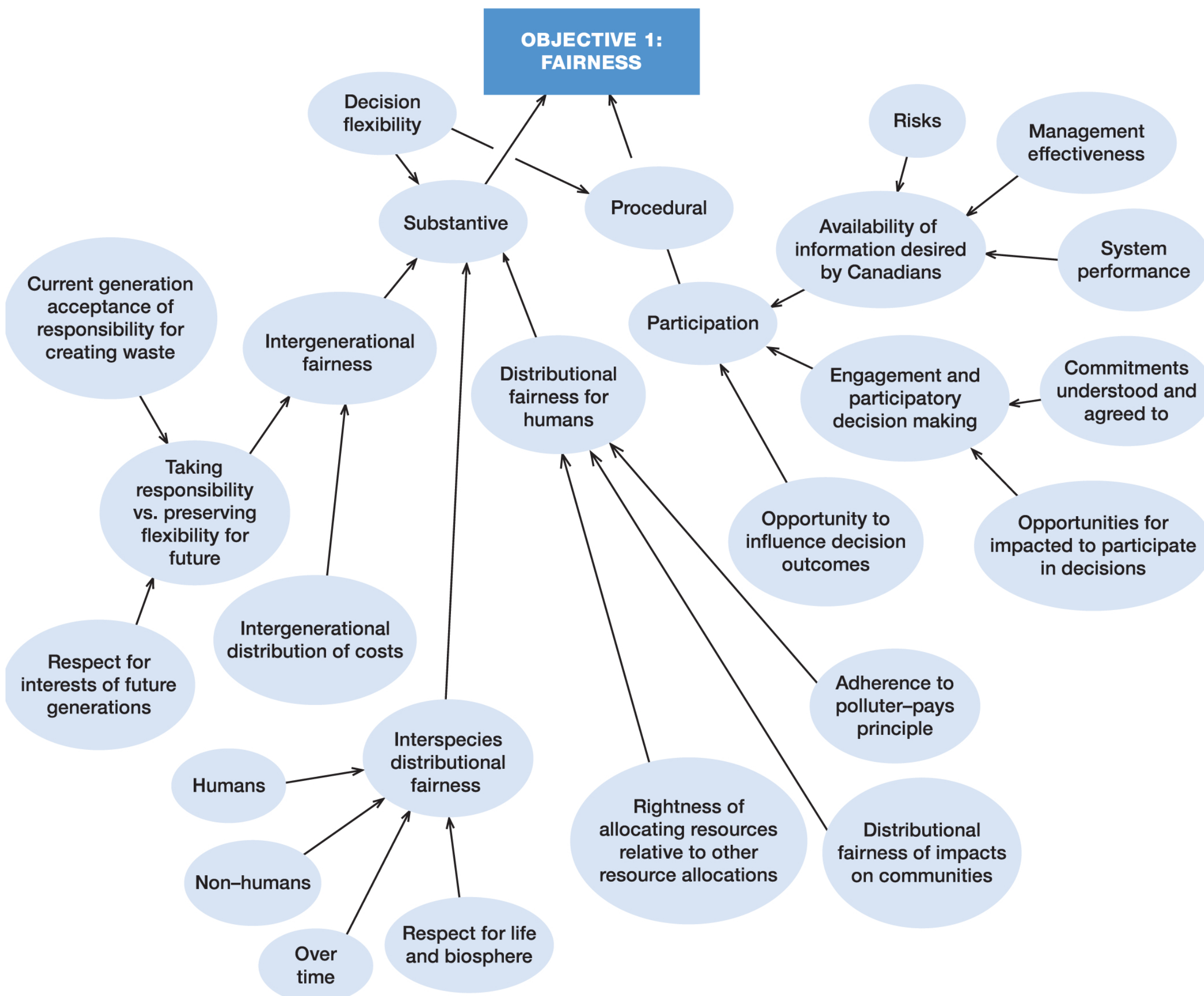

Figure 6.1: NWMO Fairness Influence Diagram, from the Final Study 2005.

otherwise), full information, and includes all of the relevant parties that have a stake in the issue. A socially acceptable decision, subsequently, is a public decision that is made in a procedurally fair manner — the decision option itself is a matter of reflecting on the best (or least-bad) compromise between the technical and ethical frameworks. The reason for including procedural fairness as a guideline or process for social acceptability is largely a matter of attempting to garner the public's trust and confidence in the proposed solution. This is important because without such trust, as is the case in the Yucca Mountain scenario, implementing a publicly acceptable solution is nigh impossible. The hope is that by keeping the siting process open and accessible, without unfairly imposing the repository on any unwilling community, the NWMO might be able to overcome public opposition and find a willing community.

While procedural fairness is an important aspect of the siting process, it is not sufficient for an ethically justified approach in the nuclear waste case. Many of the individuals affected by the repository are not presently alive, and so they cannot participate in the decision procedure. This is significant because, unlike many other decisions we make today with multi-generational ramifications, the decision cannot be reversed (at least not without massive financial cost to future people) and the potential for harm if the repository fails is severe. For these two reasons, among others, we need further conditions for the potentially fair distribution of the nuclear waste risk. The NWMO recognizes this need and has established the constraint of what it calls 'substantive fairness.'

Substantive fairness is a broad concept that "includes consideration of how the costs and benefits associated with the approach would be distributed among different people and between humans and other species. It also includes consideration of intergenerational fairness. A key question for intergenerational fairness is the balance struck between the desire that the current generation take responsibility for resolving the problem once-and-for-all versus the desire not to overly constrain future generations by the choices we make today" (Nash & Dowdeswell, 2005a, 168). These concepts, contained in the flow-chart, are more explicitly stated by the NWMO as follows:

Q10a The beneficiaries of nuclear energy should bear the (full) cost. Do not impose burdens on people who do not benefit from the activities that generated the spent nuclear fuel. This is often called the *self-sufficiency principle:* "those who produce the used fuel will assume full responsibility for its long-term management)" (Nash & Dowdeswell, 2005a, 117).

Q10b Distribute the costs, risks, and benefits fairly.

Q10c Respect the interests of future generations and nonhuman life forms.

Taken together these form the core of the NWMO's conception of fairness. Are these principles satisfied in the present nuclear case? How can we guarantee that future people will not bear our radioactive burden? What does it mean to 'respect the interests of future generations and nonhuman life forms'? These are obviously be woolly statements, and the NWMO must be clearer about the content of these claims. This lack of clarity, as is abundantly clear, pervades the entire ethical framework; a more rigorous approach to ethical groundwork is required before any positive claim about the ethical acceptability of nuclear energy can be made. In the meantime, let us continue to adopt the assumption that the NWMO's ethical framework from the Final Study is the authoritative document on the matter, and hold it up to scrutiny as such.

Before we go further, however, an important point of definitional clarification is required. Principle Q10b states that the costs, risks, and benefits ought to be distributed fairly. But it is plainly evident that this principle is circular in the present context — the principles Q10a, Q10b, Q10c are intended to *specify* what fairness means for the NWMO, and not employ the concept for which they are meant to define. Instead, it is precisely the problem in Q10b that the fairness criteria aim to solve. So we must eliminate the offending principle and keep the two other principles of substantive fairness that need to be satisfied: pay the full cost upfront for our radioactive waste management option, and respect both nature and future generations. If these are satisfied, the NWMO deems its solution a fair solution. Paying the full-cost is already being satisfied to a large extent: about $0.01 per kilowatt-hour. The conservative estimate of the final storage solution is $24 billion (CDN), and it is projected that this amount will be reached during the construction of the facility. If the cost exceeds that amount, or the user-supplied funds do not meet the actual cost of the facility, then we will have failed in our obligation to pay the full cost. Further investigation needs to be conducted about the finances of this system before we can determine its current acceptability. It is the second part of the substantive fairness principle, however, that poses a more complex problem — namely, what does it mean to 'respect nature' or respect future generations? I think that a reasonable answer can be provided by addressing the underlying question: why do we have any obligation to future people in the first place?

The NWMO's framework for substantive fairness is arguably quite thin, but we can give it more substance by examining the origins and justification of its component parts. As I mentioned in the introduction above, I will argue that its conditions for distributional fairness are plausibly derived from the philosophical work of John Rawls, as opposed to a utilitarian decision procedure bidding us to maximize expected utility. Adopting a Rawlsian approach also provides for a meaningful solution to the requirement that we respect nature, and is coherent with existing international resolutions regarding nature and future generations.

6.2 Justice as Fairness

Though the NWMO does not explicitly offer a reason as to why fairness is so important, I contend that their fairness prescription most probably arises from the influential philosophical position of *justice as fairness* developed by John Rawls (Rawls, 1971). His overriding goal is to provide a theory of justice which constrains the legitimate use of political power and which offers a framework for how to structure society's main institutions, with the basic assumption that individuals ought to be both free and equal. Given that individuals are both free and equal, to which principles for social cooperation would self-interested, rational agents agree? We are all presently entrenched in our own social circumstances — level of wealth, social status, health, political power, natural endowments, and so on — so we cannot expect rational agents to agree to fair principles so long as some individuals have some kind of superiority over others. To circumvent this problem, Rawls asks us to imagine that we are self-interested agents coming together to negotiate terms for social co-operation under what he has famously called the *original position*, with decisions made from *behind the veil of ignorance*. The original position is a hypothetical and pre-political situation (like the Hobbesian "State of Nature," only much less brutal) in which "all agents come together to bargain, as prudent and self-interested parties, on the rules that will shape the basic social institutions, in particular government" (Orend, 2002, 83). Moreover, "all such agents are, by stipulation, behind a veil of ignorance, which deprives them of information that Rawls believes would poison the bargaining session and generate slanted, unfair results" (ibid.). Under these conditions, individuals are denuded of everything except their self-interested rationality. As Rawls states explicitly, within the original position:

> The parties do not know to which generation they belong or, what comes to the same thing, the stage of civilization of their society. They have no way of telling whether it is a poor or relatively wealthy, largely agricultural or already industrialized, and so on. The veil of ignorance is complete in these respects (Rawls, 1971).

From within this situation Rawls believes that we would agree to a scheme of moderate, liberal egalitarian principles which ensure that the least-advantaged individuals are not unfairly disadvantaged. Those principles are as follows:

1. Each person has the same indefeasible claim to a fully adequate scheme of equal basic liberties, which scheme is compatible with the same scheme of liberties for all;
2. Social and economic inequalities are to satisfy two conditions:

(a) They are to be attached to offices and positions open to all under conditions of *fair equality of opportunity*;

(b) They are to be to the greatest benefit of the least-advantaged members of society (the so-called *difference principle*) (Rawls, 1971).

Self-interested agents would plausibly adopt these principles because they provide a sort of basic insurance policy just in case individuals find themselves, once the veil of ignorance is lifted from the original position, in the position of being one of the least-fortunate members of society — little natural talent, impoverished, minority status, politically impotent, and so on. That is, self-protecting rational agents will want to establish political and social structures which make the minimum position minimally decent, and structure society such that "inequalities ultimately benefit even the worst-off" (Orend, 2002). Maximizing the minimum is also known as a "minimax solution" in decision theory, of which I will have more to say shortly.

How are these principles relevant to our nuclear waste case? For our purposes, it is the second principle, directed toward the establishment of just social and economic institutions, which is most applicable. All future people will be born into a world encumbered by the social, cultural, economic, political, and environmental circumstances which we have established — and will subsequently leave for them. They are, for all intents and purposes, like potential agents in the lobby-room of the original position, waiting for their turn to lift the veil and enter the world. What are the minimally decent and fair policies or principles to which they would agree? Which set of policies lead to an equality of opportunity and offer the greatest benefit to the least-advantaged? The NWMO has tried to implement Rawls' principles through its fairness conditions. It argues, I contend, that rational agents would agree that the following principles are fair and respect the interests of the least advantaged: (i) minimize risk of harm to present and future generations; (ii) ensure that the users of nuclear power pay the full cost of waste management; (iii) demonstrate respect for both present and future generations, and the environment; (iv) ensure that procedures for selecting a waste repository site do not unfairly disadvantage the least-advantaged. If these conditions are met, then the NWMO argues that its programme is fair.

6.3 Rawls and the Maximin Decision Rule

Is maximin a good decision rule for our purposes? Nobel Memorial Prize winner John Charles Harsanyi has remarked that "the maximin principle … is a thoroughly irrational principle as a decision rule and, therefore, cannot serve as a basis for a rational ethics" (Harsanyi, 1976, x). I find that, along with Shrader-Frechette (1991; 2002) and contrary to Harsanyi's vitriolic revocation of maximin, the maximin principle — coupled with an uncontroversial version of the precautionary principle — can provide good justification for rejecting options that maximize utility under conditions of great risk and uncertainty. Usage of these two principles also explains why communities have invariably rejected the deep geological disposal option, even at the expense of greatly increased average utility in the short term.

The maximin rule is commonly employed in cases involving risk *and* uncertainty. Formally. the rule states that we should:

> identify the worst outcome of each available alternative and then adopt the alternative whose worst outcome is better than the worst outcomes of all the other alternatives (Rawls, 2001).

In the parlance of decision theory, it bids an agent to "compare the minimum utilities provided by each act and choose an act whose minimum is the maximum value for all the minimums" (Resnik, 1987, 26). In other words, *maximize the minimum*, or pick the best of the worst. The NWMO equates this with "choosing the least-bad option." If two acts have equal and maximal minimums, we should use the *lexical* maximin rule and exclude all rows except the tied ones then compare the next lowest entries until the tie is broken or the tables are exhausted (Resnik, 1987).

The rule also has wide-reaching social implications, as for Rawls "one society is better than another if the worst-off members of the former do better than the worst-off in the latter" (Shrader-Frechette, 1991b, 103). We can find expressions of this idea on the world stage when countries are ranked according to how well they treat their most disadvantaged citizens; on a more local scale, we often express the idea in pithy aphorisms like "you're only as strong as your weakest link" and "you're only as fast as your slowest player." Thus, to make the *entire* group better off, we must raise the lowest bar; utilitarians, on the other hand, would state that we only have to raise the bar upon which the *average* amount of people stand.[5]

Some people might think that Rawls advocates the use of maximin for *all* decisions. This is false. Rather he sanctions its use primarily in matters of 'fundamental' significance to the basic structure of society. However, the maximin rule is compatible with the principle of maximizing one's interests — (rational) good, or expected utility — so long as the expected utility lacks what he calls 'substantive content.' He thus strips expected utility of its relation to representing pleasure, or anything like an expression of an agreeable subjective state. Instead, "[e]xpected utility is a purely formal idea specified by a rule or mathematical function" (Rawls, 2001) representing the agent's order or ranking of alternatives.

Why have citizens and the NWMO chosen the maximin approach even though it might yield less utility overall? One conjecture is that there is too much uncertainty involved, and the risk (harm) of failure is too great to justify taking advantage of the added expected utility. We can call this the *risk-averse* option. Whether explicitly or implicitly, this tactic likely invokes something called the precautionary principle, which bids us to "[avoid] future harm associated with suspected, but not ascertained, risk factors" (Martuzzi & Tickner, 2004, 85). It essentially embodies the dictum "better safe than sorry." In a general characterization:

> When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically (Turner & Hartzell, 2004).

Models of nuclear waste-seepage have been notoriously unreliable (Shrader-Frechette, 1993a), making it clear that both the degree of harm and uncertainty are not yet

[5] My thanks to professor Mathieu Doucet insightful comments on this section.

well established. Such imprecision warrants the use of caution; to do otherwise is just reckless, regardless of utility advantage.

6.3.1 Objections to Maximin

As with every philosophical perspective (or any perspective for that matter), the maximin strategy is beset by its own unique set of problems and trade-offs. One objection commonly leveled against the view is that it is anti-progressive. Like the trite saying "no pain, no gain," this objection embodies the idea of "no risk, no gain," albeit at the expense of rhyme. Thus, even though building and operating a nuclear reactor involves tremendous risks to people and the environment, we gain a source of electricity and technological knowledge about reactor design. The maximin principle can therefore lead us to be too risk-averse. To allay fears raised by this objection NWMO may employ the precautionary principle, such that when a risk is imposed that risk must be justified, and attempts must be made to both mitigate the risk and reduce uncertainty about whether the harmful radioactive substance will find its way into the environment over time.

Second, why should we care that a few people suffer so that a large majority can benefit? This question undergirds the classic debate between utilitarians and egalitarians. I do not wish to engage that debate except to note that if our models are off by a couple orders of magnitude (very plausible given the amount of uncertainty we are dealing with) then everyone is placed in life-threatening risk lest they have the resources to relocate quite some distance away, as most of the groundwater table and agricultural land in the vicinity will become unusable. This problem becomes even more serious when we consider how the waste can seep into several rivers and find its way into the ocean, affecting people and the environment well beyond the jurisdiction of those making the decision.

6.4 Obligations to Future Persons

Rawls believes, though controversially, that justice as fairness is intergenerational. That is, just principles that self-interested rational agents would adopt in the original position are applicable to all generations, and not simply the generation which finds itself establishing the principles. Thus, he states that

> We can now see that persons in different generations have duties and obligations to one another just as contemporaries do. The present generation cannot do as it pleases but is bound by the principles that would be chosen in the original position to define justice between persons at different moments in time. In addition, men have a natural duty to uphold and to further just institutions and for this the improvement of civilization up to a certain level is required. The derivation of these duties and obligations may seem at first a somewhat farfetched application of the contract doctrine. Nevertheless these requirements would be acknowledged in the original position, and so the conception of justice as fairness covers these matters in its basic idea (Rawls, 1971, p.293).

As we can see, Rawls struggled with providing a reason for why we have obligations to future generations. For him, our obligation arises from a "natural duty." But where does this natural duty come from? To answer this it is helpful to look briefly at the concept of obligation or duty. An obligation or duty is a requirement that binds us to some action. This can arise from a variety of circumstances. We might have a political obligation or duty to obey the state and its laws, an obligation to keep our promises, a duty to respect the rights of other citizens, or a set of duties dictated by a position or terms of employment. In each of these cases a contract likely binds the relevant people or groups, wherein each member agrees to treat each other in a manner consistent with the contract. To act immorally is to violate one's obligation to comply with the contract. When a contract is broken the violator can be legitimately punished by the state or sued by the individuals harmed by the violation. But obligations to future generations cannot satisfy this mutuality demand — future people cannot consent to an agreement between us and them, and nor can they effectively reproach present people for violating a presumed obligation. They simply do not presently exist, and so they cannot *do* anything to censure our actions. Thus, if we are to have any obligation to future people, it must be a special kind of relation to a special class of non-existent entities. And therein lies the rub. How can we have obligations to non-existent entities? And if we do have obligations, what do those obligations oblige us to do? Let us deal with these two problems in turn.

The most plausible solution to justifying obligations to future generations rests in realizing that not all obligations are contractual. As Kristin Shrader-Frechette (2002b) notes, social contracts "exist even when there is no prearranged plan of explicit reciprocity," such as in the case of familial duties. This can most easily be seen in the parent-child relationship. By agreeing to bear children, parents take on the obligation to care for them. Even though some authors, like Callaghan, think that "children owe their parents a debt in return for their life ... a parent's duty is not contingent on the child's reciprocity. The parents have duties [natural duties, perhaps] regardless of whether they are ever reciprocated" (Shrader-Frechette, 2002b, 102). In other words, there can be duties without rights. The same is true, so the argument from familial obligations proceeds, for future generations. We have a so-called natural duty toward future persons in a manner similar to the duty of care that obtains between a parent and child. Thus, even if future people have no rights, we can still be said to be under duties. For example, animals don't have rights, yet we are plausibly said to have duties of non-cruelty, especially, toward them. Analogously, it would be cruel to dump a burden of poisonous waste on our descendants.

There is also another sense in which we might be said to have a natural duty, which the philosopher Edith Brown-Weiss expresses in light of our relation to the natural environment. She claims that "even if we knew that we were the last generation of the human community to live on earth, it is still not clear that we would have the right to desecrate it, or destroy it, since the human community is, in the end, only part of a much larger natural system ... " (Weiss, 1988). She elaborates on this relation in her article "Our Rights and Obligations to Future Generations for the Environment":

> . . . our actions affect the natural system. We alone among all living creatures have the capacity to shape significantly our relationship to the environment. We can use it on a sustainable basis or we can degrade environmental quality and the natural resource base. As part of the natural system, we have no right to destroy its integrity; nor is it in our interest to do so. Rather, as the most sentient of living creatures, we have a special responsibility to care for the planet" (Weiss, 1990).

Our special responsibility here (or natural duty) to care for the environment upon which we depend for life and sustenance requires, if we take intergenerational equity into account, to constrain our actions so that we pass the world on to our descendants in a particular (namely, desirable) state. This special responsibility is also enshrined in national and international agreements. At its 29th session, held in Paris in 1997, the United Nations Educational, Scientific and Cultural Organization (UNESCO) produced a document titled the "Declaration on the Responsibilities of the Present Generations Towards Future Generations"[6] in which our obligations to future generations are explicitly stated. Two of the most presently relevant Articles from that document are:

> **Article 4** — *Preservation of life on Earth.* The present generations have the responsibility to bequeath to future generations an Earth which will not one day be irreversibly damaged by human activity. Each generation inheriting the Earth temporarily should take care to use natural resources reasonably and ensure that life is not prejudiced by harmful modifications of the ecosystems and that scientific and technological progress in all fields does not harm life on Earth.
>
> **Article 5** — *Preservation of the environment.*
> (1): In order to ensure that future generations benefit from the richness of the Earth's ecosystems, the present generations should strive for sustainable development and preserve living conditions, particularly the quality and integrity of the environment.

[6] <http://www.unesco.org/cpp/uk/declarations/generations.pdf>.

> (2): The present generations should ensure that future generations are not exposed to pollution which may endanger their health or their existence itself.
> (3): The present generations should preserve for future generations natural resources necessary for sustaining human life and for its development.
> (4): The present generations should take into account possible consequences for future generations of major projects before these are carried out.

The National Academy of Public Administration (NAPA) in the U.S. has also adopted similar principles, and they recognize the difficulty in establishing internationally accepted principles for a framework of intergenerational equity. The organization observes that "When making fundamental policy decisions, the question is how does one generation equitably take into account the interests of future generations. It is clear from the relevant literature that there are no commonly agreed-upon principles or doctrine, either in public administration or any other discipline, that fully define how to make such policy decisions" (NAPA/NEA, 1997, 1). Nevertheless, there is some common overlap that suggests some general agreement about the right sort of obligations that are required to treat future people fairly. For NAPA those obligations or guiding heuristics are:

> (a) no generation should [needlessly] deprive its successor of the opportunity to enjoy a quality of life similar to its own; (b) every generation is the trustee for those that follow; (c) there is an obligation to protect future generations provided the interests of the present generation and near-term generations are not jeopardized; (d) near-term concrete hazards have priority over long-term hypothetical hazards; (e) however, this preference for the present and the near-future is reduced where questions of irreversible harm for future generations are concerned; (f) when action poses a plausible threat of catastrophic effects, then that action should not be pursued absent some significant countervailing need; (g) the reduction of resource stocks entail a duty to develop substitutes (NAPA/NEA, 1997).

All of these formulations of our special responsibility bid us, at minimum, not to leave the world worse off. The important part for our present discussion is that the NWMO claims to satisfy this special responsibility through the implementation of its ethical framework, and specifically the "minimize risk" and fairness principles. We cannot, however, merely rely on the notion of a special responsibility to convince people that these are the right sort of principles that we should adopt. Indeed, we don't have to. These duties can be derived, so I shall argue, from the basic assumption that Rawls' concept of *justice as fairness* best undergirds what the NWMO means by fairness.

To see how our special responsibilities follow from the Rawlsian framework, let us assume that we have an obligation not to leave the world — the environment and future generations — worse off. The future inhabitants of the world can be left worse off in either of two ways from a radioactive waste programme: (1) They have to pay for the cleanup and management of our nuclear waste; or (2), radioactive fuel waste leaks or otherwise enters the environment and puts the health of living beings at risk. By implementing a "user-pays" scheme for funding the repository, and minimizing the risk of failure of the repository from a technical standpoint, the NWMO does the best that it can to abide by the Rawlsian fairness requirements. To determine whether this is true, or sufficient, we need to examine the conditions within the framework of the original position. Would a rational and self-interested individual agree to a practise where, for instance, the NWMO passes the cost of a nuclear repository on to future generations? For individuals alive today, that may very well be acceptable. Why pay for something today when we can use that money for something else and let our unborn descendants pick up the tab? (In economic and corporate parlance, such a practise is known as "externalizing" costs.) However, since we are in the original position, denuded of information about our physical health, social or political status, or even about the time period in which we will live, the answer is not likely to be so wantonly callous. Instead, there is a strong disincentive to accept a scheme other than that put forward by the "user-pays" principle because there is a (hypothetical) chance that we could be a member of a generation that ends up paying for managing the waste of a previous generation. Such a scheme, so the Rawlsian would argue, is patently *unfair* (and unjust) to people who did not benefit directly from the use of nuclear energy.

The same is true for the broad consideration of risk. Assume, contrary to fact, that the NWMO has an obligation to maximize risk. Is this principle be reasonable? Quite clearly the answer is no; such actions would be both unfair and inhumanely cruel. Lack of acceptability formally arises because people have a right not to be intentionally harmed, or harmed by actions that are foreseeably likely to cause harm. In our present case, just as we have a duty not to intentionally expose our children to actions that are likely to be a physical detriment to their health or well-being, we have the same obligation of non-harm toward future generations. Thus, if exposing our children (or other living humans) to harmful radiation is wrong, then so is leaving an environment contaminated with harmful levels of radiation that future people will one day inhabit.

We cannot, of course, prevent *all* potential exposure of risk, so there is some limit to the extent of our obligation. For this reason the NWMO has adopted the "minimize risk" condition, instead of something like an "eliminate all risk" principle. The best that we can do is build a repository, based on the best available scientific evidence, that *minimizes* the potential risk of harm — such as radiation exposure or environmental damage — to present people and future generations. Does this satisfy the fairness condition though? Would a rational and self-interested agent agree to the minimizing risk condition in the original position and behind the veil of ignorance? For the management of existing waste, the answer must be yes. The alternative options are not reasonable if one is rationally unbiased. For example, we might choose to dump our waste cheaply in the Canadian hinterland, where it will only affect a few relatively impoverished individuals; the vast majority of the Canadian population will therefore be at minimal risk of exposure, and quite likely to accept such a solution. Why should we object, if we find ourselves living far away from the storage site, to such a proposal? At first glance this is quite reasonable for any rational individual who cares about maximizing their own welfare. Indeed, it is a good solution, so long as you don't find yourself within the vicinity of the storage site. But the NWMO, the Roundtable on Ethics, and Canadians consulted during the public information sessions regarding the proposed waste repository procedure, all believe that dumping the waste on an unwilling and remote community would be an ethically bad solution. Their reasoning here, so I claim, is informed by their adherence to the Rawlsian notion of justice as fairness. It is ethically bad to dump the waste in such a manner because no rational agent would consent to such an arrangement in the original position. Why? Because when the veil is lifted, we might find ourselves living inside the community that has been forced to care for Canada's nuclear waste. Such an arrangement would unfairly disadvantage those individuals, both financially and in terms of health.

The situation is different, according to the NWMO, if members of a community *consent* to a repository in their community, and do so with the best available information and free from financial coercion.[7] The reasoning here is precisely what the NWMO specifies in its conditions of "procedural fairness." If the NWMO satisfies its substantial fairness obligations, and the community agrees to voluntarily host the facility after having fully weighed the costs and benefits, then the repository siting is deemed to be a fair and ethically acceptable arrangement. That, at least, is the "least-bad" ethical solution to the problem of storing Canada's nuclear waste.

A least-bad solution, however, is not equivalent to an ethically well-justified solution. As we saw in chapter 1:

> Since "something" has to be done with the [existent] wastes, a least-bad solution is morally acceptable if that is the best there is. Whereas for creation of new wastes to be morally acceptable, there must be not just a least-bad management solution, there must be a genuinely good solution.[8]

In order for the repository to be well-justified it must satisfy all of the ethical principles, and not merely offer the "best available solution given the circumstances." To

[7]Professor Mathieu Doucet brought an interesting point to my attention on this matter. What does it mean to say that the decision should be made free from financial coercion, given that the only reason (or at least the overriding reason) for accepting the repository *is* financial? This is a concern that needs serious attention from within the social framework for public acceptability.

[8]Roundtable minutes 17 November 2004. See also (Brook et al., 2005).

meet this condition the NWMO must be sure that risk will be minimized for the duration of the repository's lifetime. Unfortunately, this is not possible for two important reasons.

First, minimizing risk requires that the containment structure remains secure for eons; anything less than total containment does not fully minimize risk. However, due to the various types of inherent uncertainty with projects of this type, there is no way to guarantee secure containment. For instance, the containers that we use to store the waste may become embrittled over time by the radiation and subsequently behave in unpredicted ways (i.e., they may fail sooner than expected). For this reason the NWMO has adopted the multiple-barriers (or defence-in-depth) approach to account for such possibilities. But there is no guarantee that multiple-barriers will not fail, too, especially if there is tectonic activity or the region is covered by either water or an ice-sheet. Regardless, multiple-barriers are useless if there is individual or political willpower to interfere with the facility. It is impossible to guarantee stable and effective political institutions that will ensure the safety of the radioactive waste facility for several millennia. The NWMO admits this much, that in truth "the NWMO cannot ensure the safety of the approach because of a whole host of uncertainties."[9] But without such security, future people (and the environment) *may* be exposed to our waste without consent, and they will have to bear the cost of either protecting themselves or cleaning up our radioactive burden.[10]

Second, radioactive waste is *irreversible* and harmful for several millennia. Once the waste has been created it cannot be undone, and nor can be it re-purposed without creating even more deadly radioactive waste (as in the case of reprocessing nuclear fuel). Furthermore, no chemical or technical process can reduce its inherent toxicity — only after thousands of centuries will the radioactive waste decay enough to approach the original toxicity of when it was first removed from the ground. As the NWMO admits: "The radiotoxicity analysis for used CANDU fuel suggests that

[9] Roundtable meeting minutes 8 June 2004.

[10] If the containment is breached — by either natural or human means — then principle 5.2 is violated: "The present generations should ensure that future generations are not exposed to pollution which may endanger their health or their existence itself."

this material is a potential internal exposure health risk for more than one million years . . . therefore, to fully minimize the risk, . . . one could conclude that used nuclear fuel poses a hazard which needs to be managed for one million years or more" (Nash & Dowdeswell, 2005a, 343-4). Is it reasonable to expect that our facilities will last for a million years, let alone one thousand or ten thousand years? Obviously not. And the burden of attempting to keep the waste contained will fall on *all* future generations; this is a burden for which they receive none of the direct benefit, and a significant portion of the cost and risk. Finally, since the radioactive waste is both lethal and harmful, irreversible, and the security of the containment facility cannot be guaranteed because of inherent technical and political uncertainty over the lifetime that it is required to operate, we cannot legitimately say that the 'respect for nature' and future generations condition can be presently satisfied for waste arising from newly commissioned reactors. It would therefore be unfair to unduly burden future people with such a risk. We will, of course, burden them with the waste that we have already created; but we cannot say that imposing the burden of new waste is a fair imposition.

Chapter 7

Conclusion

> ...the price that we demand of society for this magical energy source is both a vigilance and a longevity of our social institutions that we are quite unaccustomed to (Alvin Weinberg, 1972).

Using nuclear power to meet our energy demands is justified, according to the International Atomic Energy Agency, if "it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes," with the provisos that the risk of harm be kept "As Low As Reasonably Achievable," and an individual's radiation exposure dosage does not exceed the threshold established by national radiation standards. The ***benefits*** for any nation using nuclear power are substantial: jobs and a significant supply of base-load electricity to meet the domestic and industrial needs of a populace.[1] On the other hand, the *costs* we incur — apart from the massive direct costs of construction — are the requirements to isolate the carcinogenic and potentially lethal waste from humans and the environment for time immemorial. To meet this responsibility the Nuclear Waste Management Organization (NWMO) seeks to bury Canada's nuclear fuel waste in a Deep Geological Repository, with the options of monitoring the nuclear waste over time while retaining the possibility of

[1] I have left out the putative benefits propounded by the Canadian Nuclear Association, namely that nuclear power is "clean, reliable, and affordable." These statements are false. See the introduction and Chapter 4 for a fuller discussion of these claims.

retrieving the spent fuel at some later date; it calls this approach Adaptive Phased Management (APM).

A straight-forward analysis of the costs and benefits involved in using nuclear power, however, is not sufficient for an ethically well-justified approach to the long-term management of Canada's nuclear fuel waste. The primary reasons against such an approach are that: unlike other such calculations, a large portion of the risk posed by nuclear waste is borne by people who do not benefit directly from its use but still bear the costly burden of its safekeeping; the impossibility of obtaining informed consent for a repository from future people; and concerns about the technical and social uncertainty regarding whether or not the waste will remain secure over thousands of years. The NWMO recognizes these difficulties, and thus it states that "given the nature of the hazard it is imperative that we consider matters of "equity" and fairness within the current and future generations"(Nash & Dowdeswell, 2005a). For this reason, the NWMO has supplemented the standard utilitarian cost-benefit approach with a set of principles contained in its ethical framework which, if satisfied, it believes will offer good grounds for an ethically acceptable solution to the management of nuclear waste. The full set of principles was offered at the end of Chapter 1, but in general these principles require the NWMO to show:

> respect for life in all its forms, including minimization of harm to human beings and other sentient creatures; respect for future generations of human beings, other species, and the biosphere as a whole; respect for peoples and cultures; justice (across groups, regions, and generations); fairness (to everyone affected and particularly to minorities and marginalized groups); and sensitivity to the differences of values and interpretation that different individuals and groups bring to the dialogue (Nash & Dowdeswell, 2005a, 366).

These vague principles, coupled with the complexities of situating the ethical constraints in a practical context, make the task of developing an ethically acceptable framework particularly difficult. Classic ethical theories do not offer much guidance in such contexts. Rather, we need to take a pluralist approach to offering ethical guidance so that we can meaningfully situate the ethical principles in this variegated, practical context; our ethical constraints need to reflect existing circumstances, and adapt accordingly. For example, in some aspects we may need to make a utilitarian cost-benefit analysis regarding how much extra concrete should be used to contain a radioactive waste canister. But we also impose a duty — deontological — not to expose the population to a level of radiation above a set standard limit, regardless of whether or not a cost-benefit analysis suggests that exceeding the limit would be rationally or financially justified. (Hence we are dealing with what the NWMO calls an 'ethical framework' and not a unified 'ethical theory.') Nevertheless, despite the desirability of a pluralist approach here in the field of applied ethics, the particular ethical rationale, assumptions, and reasons for decisions regarding our solution to nuclear fuel waste management need to be made explicit. That is the purpose of an established ethical framework; it should provide consistent, articulate, and informed guidance in the relevant practical context. Unfortunately, even by the NWMO's own admission, it has not conducted an in-depth evaluation of the principles in the ethical framework. The main objective of this dissertation, therefore, has been to remedy that defect, in part, by critically evaluating the two most vital principles to which the NWMO's framework appeals: utilitarian justification and a form of Rawlsian fairness. To this extent, the main objective has been a matter of providing much needed clarification so that we can further develop an acceptable ethical framework in Canada in relation to both our present nuclear circumstances and in relation to the other frameworks.

This thesis has thus taken the NWMO's ethical principles to be authoritative, and worthy of the most serious and sustained scholarly attention. They are, after all, the principles endorsed by Parliament and the product of some of Canada's most distinguished ethicists. The results of such attention, as given in this thesis, are:

(1) Sustained research and thought on the applied ethics of nuclear power in Canada, and especially nuclear waste, are scant. One goal was merely to advance reflection in this regard, and call attention to a serious practical problem for decision-makers and Canadian citizens. Arguably the best such research and thought in recent history has been the NWMO's "Roundtable on Ethics," convened and written by some of Canada's

most respected ethicists. But their deep questioning and concerns, raised during their meetings throughout the proposal's development, were significantly diluted in the final product.

(2) The NWMO's criteria and principles are either (a) seriously vague and unhelpful; or (b), where substantial and helpful, the scientific evidence and the nature of the practise show that they cannot be met or satisfied. As a final result, then:

(3) It is deeply questionable whether nuclear power in general, and especially the issue of nuclear waste in particular, can ever be deemed ethical in Canada; we may, however, have a 'least-bad' solution.

The nuclear genie — ugly, dangerous, and destructive — is out of the bottle, and not only will it not go back in, our "solution" to the waste it leaves behind is to try to cram it into a new bottle and bury it, where it will remain "out of sight and out of mind." The substantial practical and moral hazards of this plan have been laid bare throughout this dissertation, and perhaps the ultimate conclusion is that we cannot morally justify this practise at all, and are left at a place the Roundtable on Ethics vaguely suspected we might end up: a bleak corner where we have no ethically justified way out and must admit that we're just trying to ensure the waste will remain secure, and hoping that the plan will still somehow work and the benefits will outweigh the costs over time.

This is a negative conclusion, so to speak, but it is important to recall that it counts as a contribution to knowledge to show how present theories, or practises, either fail or do not work. What might work? That's a multi-million dollar question — one for which we as Canadians deserve an answer — but that is for another project and, frankly, given the results of this study, one for which the way ahead seems dark. What we are left with is a situation in which we potentially have a 'least-bad' solution for managing existing wastes, but it is *not* an ethically acceptable solution. This result has important ramifications for the future of Canada's nuclear industry. In the words of the NWMO: "for the creation of new spent fuel to be ethically justified, it would have to be shown that there exists a management option that is ethically sound, not just least bad" (Nash & Dowdeswell, 2005a). Given the result of this document, we acted unethically by generating the waste in the first place, but we now know that it is gravely imprudent, disturbing, and wrong to continue along our ethically indefensible path by producing even more nuclear waste. Hindsight has helped us realize the presently unethical nature of nuclear power, but it will take a change of ethical heart, and an act of political will, to transform the ethics of nuclear waste in Canada from the sad state it is currently in.

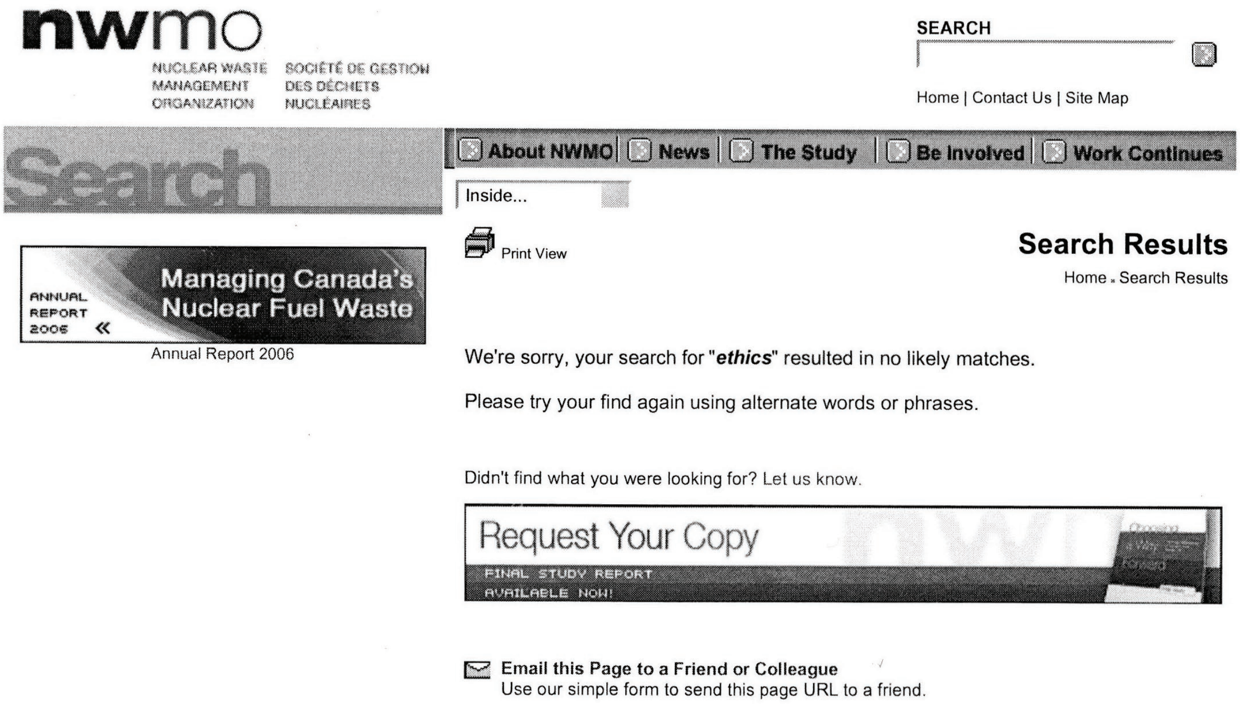

Figure 7.1: A search for ethics yielded no results. <www.nwmo.ca >

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