NWMO
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Asking the Right Questions?

The Future Management of Canada's Used Nuclear Fuel

Our Mission

The purpose of the NWMO is to develop collaboratively with Canadians a management approach for the long-term care of Canada's used nuclear fuel that is socially acceptable, technically sound, environmentally responsible and economically feasible.

Asking the Right Questions?

The Future Management of Canada's Used Nuclear Fuel

Discussion Document 1

Contents

Chairman's

The Nuclear Waste Management Organization (NWMO) is pleased to present this paper for public discussion and comment.

This is the first of three discussion documents to be published as part of the NWMO study of approaches for the long-term management of Canada's used nuclear fuel.

The key purpose of this paper is to invite comment on the issues to be raised and questions to be asked as the NWMO analyzes different management approaches.

A second discussion document will follow in 2004. In that paper, we will share early results of our assessment of different management approaches.

Finally, a third document will be released in 2005; it will present the NWMO's draft recommendations and implementation plans. This will enable the NWMO to benefit from further public comment and advice so that we may finalize the study and submit it to the Minister of Natural Resources Canada.

The NWMO undertakes this work in fulfillment of its legislated obligations under the *Nuclear Fuel Waste Act*. In 2002, consistent with the Act, Canada's nuclear energy corporations established the NWMO to engage Canadians in a comprehensive study of approaches to the long-term management of used nuclear fuel.

Also in fulfillment of the Act, the NWMO's Board of Directors appointed an Advisory Council, under the stewardship of the Honourable David Crombie, whose independent comments on the study will be provided to the Minister.

The NWMO must submit its final study to the Minister of Natural Resources Canada within three years of the Act coming into force; that is, by November 15, 2005. That is not a long time to conduct such a study, but the NWMO Board of Directors is committed to fulfilling the expectations of the legislation. This paper represents another important milestone in support of the NWMO's legislative requirements for this study under the *Nuclear Fuel Waste Act*.

This document is important for a number of reasons:

- **First, the issue before us requires a public dialogue, one that extends beyond nuclear industry circles.**

While scientific and technical rigour is a must, the *Nuclear Fuel Waste Act* reminds us that the issue before us is one of many dimensions. We must consider ethical and socio-economic implications, as well as traditional knowledge and the understandings of aboriginal people, and financial sustainability. These issues are not addressed in technical and engineering concepts.

Rather, we are best informed on these matters by the direct input of Canadians. This paper seeks to encourage this dialogue by inviting comments from the public on whether we are "asking the right questions" as we formulate our study framework. We will be guided by the input received.

- **Second, this and subsequent discussion papers will assist us in fulfilling our requirements under the *Nuclear Fuel Waste Act*, with respect to consulting and reporting back on comments of Canadians.**

The legislation requires us to consult and summarize comments of the general public and aboriginal people in our final report. The more we are able to capture the views and expectations of Canadians as we formulate the study at the outset, the richer our study will be when submitted to the Minister.

Message

- **Third, public input received will enable us to target our resources most effectively as we complete the study within the timeframe specified by the *Nuclear Fuel Waste Act*.**

By publishing discussion papers at milestones in our study, we hope to draw out the views and concerns of different communities of interest, so that the key issues are brought to the fore and addressed in subsequent steps in our study plan. We look forward to taking stock at key checkpoints, inviting input and canvassing Canadians on our proposed directions. We are building a rich base of input step by step, through sequential phases of public consultation. This is also consistent with requests we received in the early months of the NWMO's consultations.

- **Finally, in issuing the discussion papers, the NWMO seeks to ensure a high measure of transparency in the NWMO's work - transparency as to how the NWMO intends to approach the study, how we are interpreting our early findings, and equally important, how the public may become involved.**

This particular discussion paper is key in setting out background information on the subject of used nuclear fuel management in Canada and its genesis. We hope to introduce and make accessible a topic that is admittedly complex, but which calls for the contributions and perspectives of individuals across the country.

This is only the beginning of an important dialogue and opportunities for public engagement do not end with the submission of our study to the Minister of Natural Resources Canada in late 2005. As the Minister considers the implications of the NWMO recommendations, the Minister may proceed to consult further with the general public.

After the government decides on the approach to be taken, opportunities for public consultation will continue, and include the environmental assessment and licensing processes of regulatory authorities.

Today, Canada's nuclear energy corporations are safely managing used nuclear fuel, meeting or exceeding all regulatory requirements of the Canadian Nuclear Safety Commission. Looking to the future, the NWMO is committed to ensuring the long-term management of used fuel in a safe and socially responsible way.

To help the NWMO plan for the future management of used nuclear fuel, we hope that you will share your views on the NWMO study plan and discussion papers. The NWMO wants to understand the views of Canadians as we study the best way to ensure the long-term safety of used nuclear fuel.

Chapter 5 provides contact information so that you can forward your comments to the NWMO on the issues raised in this first discussion document. We look forward to hearing your thoughts on whether or not we are asking the right questions.

Richard Dicerni, Chairman
November 2003

Foreword

In the early years of a new millennium it is not surprising that society is asking questions. It is a time of transition in which it seems natural to take the measure of where we are, where we are headed and where we want to go.

This document begins a process of dialogue with Canadians which will attempt to seek answers in one domain – the long-term management of used nuclear fuel. It is only a first step in defining the problem, communicating potential choices and posing a way of assessing the alternatives.

How we approach this challenging issue will say a lot about our values and priorities as a society – how we want to live. It will set a benchmark for how we as a society will discharge our responsibility to manage the many wastes from the technologies we use to support our quality of life.

Most would come to consensus about broad societal goals of peace, freedom, human well-being and a resilient and productive environment. The disagreements are exposed when we chart a path to implement those goals. How do we accommodate the desires of the current generation while recognizing that the decisions we make now may affect the lives of our children, their children and many generations to come? How heavily should we rely on emerging technologies? What forms of institutions and governance inspire trust and confidence?

These questions and more are fundamental to meeting the challenge of managing used nuclear fuel in an appropriate and acceptable manner. This is an issue that requires the best of science and technology. But to respond to the fears and insecurities of Canadians, the unknowns and the complexities, as well as the optimism and hope demands a broader framework for analysis. Understanding the dynamic interaction and tradeoffs between nature, technology and society over hundreds, if not thousands of years challenges both our ingenuity and our common commitment to find a solution.

That is why we are asking you to reflect and to help guide us. Have we captured well the essence of the problem? Are we asking the right questions, be they ethical, social, environmental or economic? Are we focusing on the technical methods which are likely to hold the most promise for Canada?

The description of the problem, the set of key questions identified and the selection of the technical methods as focus for the study have emerged from our preliminary conversations with a broad cross-section of Canadians. We believe we are reflecting the direction of Canadians. Have we listened well? Have we understood the perspectives of various citizens and communities of interest? If not, help us understand what changes, what adjustments need to be made in order for this study to address the priorities and concerns of Canadians.

We intend to mine the lessons of the past, to examine the present and imagine the future in our quest for answers. We will continue to probe, to seek insight from other countries and from other areas of public policy. We are particularly grateful to those who have already contributed to our understanding of their concerns and perspectives about how we should proceed.

We hope that this document will provoke discussion and participation in the next steps. For some it may be a lengthy read, with too much technical detail. For others it will not be comprehensive enough. Our challenge was to provide sufficient information to illustrate the complexity of the task. Much more information can be found on our website.

We invite all interested Canadians to help shape the study and ultimately our recommendations to government. This opportunity will continue throughout our work as we intend to keep people informed of our thinking at every stage of the study. While we assume full responsibility for the quality of our work, it will be enriched immeasurably by your contributions.

Elizabeth Dowdeswell, President
November 2003

Executive Summary

"Asking the Right Questions? The Future Management of Canada's Used Nuclear Fuel," is the first Discussion Document issued by the Nuclear Waste Management Organization (NWMO). It is an invitation for Canadians to reflect on the complex issues posed by used nuclear fuel and to provide their perspectives on various approaches for its long-term management and how those approaches should be evaluated.

Canada's 22 licensed commercial power reactors have produced about 1.7 million used nuclear fuel bundles since the first unit began generating electricity more than 30 years ago. If all of the bundles were piled like cordwood, end-to-end and to the top of the boards, they would fit into five standard hockey rinks. Approximately 85,000 additional bundles are generated each year. And, if the existing reactors run to the end of their currently projected lives, it is estimated that about 3.6 million bundles of used fuel will result.

Used nuclear fuel is highly radioactive and is very dangerous to humans and the environment if it is not properly managed. In Canada, used nuclear fuel is safely managed by its owners in wet or dry storage facilities at reactor sites, meeting or exceeding regulatory requirements of the Canadian Nuclear Safety Commission. Current storage provisions at the reactor sites are intended as an interim solution. Like many other countries, Canada is now on a path to carefully consider a long-term management approach.

The NWMO was created by Canada's major owners of used nuclear fuel to meet their obligations under the *Nuclear Fuel Waste Act*, 2002. The organization's mandate is to conduct a comprehensive study of approaches for the long-term management of used nuclear fuel, to recommend a preferred approach to the Government of Canada, and to implement the approach approved by the Government on the recommendation of the Minister of Natural Resources.

The NWMO has committed to "develop collaboratively with Canadians a management approach that is socially acceptable, technically sound, environmentally responsible, and economically feasible." The *Nuclear Fuel Waste Act* requires the organization to consider three methods: deep geological disposal; storage at nuclear reactor sites; and centralized storage, either above or below ground. The NWMO may also consider other methods. This first Discussion Document describes additional options which could be considered, including some methods that are receiving international attention and several others which have been proposed at different times but are of little interest today.

A broad range of individuals and communities of interest are being engaged in an open and transparent dialogue to build the analytical framework the NWMO will use to assess the various management approaches it considers. The framework will consist of a series of questions to be asked and answered for each of the approaches, and a process for comparing the alternatives.

To ensure that development of the analytical framework is driven, from the outset, by the values of Canadian society as a whole, as well as those communities of interest who have chosen to engage on this issue, and that it captures the particular perspectives of aboriginal peoples, the NWMO convened the following activities:

Early Conversations. In an early phase of activity, public opinion research was conducted across Canada and a series of Conversations About Expectations was initiated with more than 250 individuals and organizations to learn about the issues that mattered to Canadians and to seek views about how the study should be conducted.

Envisioning the Future. In late Spring 2003, 26 individuals were drawn from a variety of backgrounds and communities across Canada and constituted as an NWMO Scenarios Team. The team developed a number of possible future scenarios as background for further testing of the adequacy of various long-term nuclear waste management approaches being considered.

Exploring Concepts. The NWMO commissioned a series of papers to explore several key concepts which are often used to understand and identify solutions to difficult public policy issues. The topics are closely related to many issues and challenges raised with us during the early conversations with Canadians.

Alternative Perspectives. Another series of commissioned papers and expert workshops identified broad questions and requirements in a host of expert knowledge areas including: ethics, traditional aboriginal knowledge, environment, nuclear waste host communities, science and technology, finance and law, and international best practice.

The activities described above were aimed at identifying issues, concerns, challenges and uncertainties expressed by Canadians in preliminary discussions. From this foundation an early sense of the questions that will form the backbone of the analytical framework is emerging. In time, answers to questions like these will provide a basis for comparing various management approaches.

The listing of questions outlined in this Discussion Document is intended to spark discussion and generate feedback. (See next page.)

Once the key questions are determined, detailed criteria will be developed – all of which will have to be addressed and their relative significance established as we assess the different management approaches. Direction on the scope and weighting of the questions will come from further engagement with experts, stakeholders, and Canadians at large.

The NWMO is committed to sharing its thinking as it evolves. Its dialogue will proceed in stages with periodic reporting points, allowing people to think through issues over time and contribute their reflections to shape the study.

A second major Discussion Document, “Understanding the Choices”, will be issued in Mid-2004. It will further develop the analytical framework as modified through dialogue with Canadians, and it will provide a preliminary comparative assessment of the management approaches.

In early 2005, the Draft Final Report, “Choosing a Way Forward – Draft”, will be released. It will provide a refined comparative assessment of the management approaches, propose implementation strategies, and present a draft set of recommendations for review prior to their finalization and submission to the Minister of Natural Resources Canada by November 15, 2005.

KEY QUESTIONS	
OVERARCHING ASPECTS	
Q-1. Institutions and Governance	Does the management approach have a foundation of rules, incentives, programs and capacities that ensure all operational consequences will be addressed for many years to come?
Q-2. Engagement and Participation in Decision Making	Does the management approach provide for deliberate and full public engagement through different phases of the implementation?
Q-3. Aboriginal Values	Have aboriginal perspectives and insights informed the direction, and influenced the development of the management approach?
Q-4. Ethical Considerations	Is the process for selecting, assessing and implementing the management approach one that is fair and equitable to our generation, and future generations?
Q-5. Synthesis and Continuous Learning	When considered together, do the different components of the assessment suggest that the management approach will contribute to an overall improvement in human and ecosystem well-being over the long term? Is there provision for continuous learning?
SOCIAL ASPECTS	
Q-6. Human Health, Safety, and Well-being	Does the management approach ensure that people's health, safety, and well-being are maintained (or improved) now and over the long term?
Q-7. Security	Does this method of dealing with used nuclear fuel adequately contribute to human security? Will the management approach result in reduced access to nuclear materials by terrorists or other unauthorized agents?
ENVIRONMENTAL ASPECTS	
Q-8. Environmental Integrity	Does the management approach ensure the long-term integrity of the environment?
ECONOMIC ASPECTS	
Q-9. Economic Viability	Is the economic viability of the management approach assured and will the economy of the community (and future communities) be maintained or improved as a result?
TECHNICAL ASPECTS	
Q-10. Technical Adequacy	Is the technical adequacy of the management approach assured and are design, construction, and implementation of the method(s) used in the management approach based on the best available technical and scientific insight? (By method, we mean the technical method of storage or disposal of the used fuel.)

Following the publication of each report, the NWMO will actively seek public comment, critique and dialogue before taking the next step. The NWMO will pursue a wide scope of opportunities to engage Canadians on the issues raised in Discussion Document 1, including roundtables, meetings, consultations with aboriginal peoples and nuclear reactor site communities, as well as activities focused on the perspectives of the general public. Central to the organization's outreach to the public will be web-based activities including e-dialogues, ongoing on-line deliberative surveys, and the opportunity to make on-line electronic submissions. National Citizens' Dialogues will be conducted in 2004, to provide further insights into the values closely held by Canadians across the country.

Through these formal and informal activities, the NWMO intends to pursue several key questions with Canadians:

Has the problem been described correctly? Are the descriptions of the issue, the challenge facing Canada today, and the characteristics of Canada's nuclear fuel inventory clear and understandable? Is there anything that should be added?

Have the appropriate ways to deal with the problem been identified? Given limited time and resources, on which technical methods should the NWMO focus? Is the preliminary depiction of these methods accurate? Is the proposed list of methods to be studied a fair basis for developing an approach for Canada?

Have the right questions been asked? Importantly – as different methods are assessed, are the issues that matter being captured? Are the correct parameters and questions suggested in Discussion Document 1? Are there specific issues that should be considered as different technical methods are assessed? What are some considerations for an implementation plan and overall management approach?

Is the proposed decision-making process understandable and appropriate? Have the key elements been captured? Are there other considerations that should be included?

The NWMO will use the input it receives to further develop and refine the management approaches and to then apply the analytical framework in preparation for publication of the preliminary comparative analysis of options in its second Discussion Document.

The NWMO website **www.nwmo.ca** is the main repository of information about NWMO activities. The NWMO invites the active participation of Canadians, and looks forward to receiving comments.

The NWMO can be contacted at:

Nuclear Waste Management Organization
49 Jackes Avenue, First Floor
Toronto, Ontario, M4T 1E2 Canada
Tel: 416.934.9814 or 1.866.249.6966

Electronic submissions are welcomed at:
www.nwmo.ca

Chapter 1 / Introduction

Purpose of the Discussion Document
The NWMO Mandate
The Context
The NWMO Approach

The NWMO has set out on a challenging quest to address the complex set of ethical, technical and related public policy issues involved in managing used nuclear fuel over the long term.

It is not a journey that can be undertaken by a small, elite, isolated group. Rather, it is a journey that invites the perspectives of a broad cross-section of Canadians. All are welcome and important participants.

Many individuals and organizations are and will be involved in this study; many have generously communicated with us already (see Appendix 1). This preliminary contact has been of considerable importance in shaping our study plan and in educating us about the issues that matter to Canadians. For their willingness to work with us, we are very grateful. We recognize that their participation in no way implies agreement with the NWMO, in terms of the nature of the process, the way ideas are expressed, or the substance of any future recommendations.

In addition, the study is benefiting from important technical input from the nuclear industry – which through its experience in managing used nuclear fuel over the years has valuable factual information and expertise to share.

PURPOSE OF THIS DISCUSSION DOCUMENT

The Nuclear Waste Management Organization (NWMO) is pleased to issue this first Discussion Document as a means of inviting Canadians to reflect on the complex issues posed by the long-term management of used nuclear fuel. It is important that we hear and understand your views about how we should evaluate approaches to managing Canada's used nuclear fuel for the future.

Each year, approximately 85,000 used fuel bundles are created in Canada when all reactors are in full operation. To date, about 1.7 million used nuclear fuel bundles have accumulated. In regulating the management of used nuclear fuel today, the Canadian Nuclear Safety Commission ensures that this used fuel is stored safely. However, this storage was only intended to be an interim solution. Canada is now on a path to carefully consider the best approach to managing used nuclear fuel over the long term.

Recent federal legislation has required the establishment of the NWMO; its mandate is to conduct a comprehensive study of approaches for the long-term management of used nuclear fuel. This Document articulates how the NWMO proposes to fulfill this legislated mandate. As we work to fulfill our obligations, our organization's objective is to develop collaboratively with Canadians an approach that is socially acceptable, technically sound, environmentally responsible and economically feasible.

We want to explore with Canadians the fundamental issues and priorities that you feel should be addressed in our study. This Document invites you to share preliminary thoughts on what values, issues and considerations should be integrated into our study.

The Discussion Document is intended to:

- **describe our legislative mandate, and how we propose to undertake the study;**
- **share, for discussion, some of the broad issues and concerns that have arisen in our early conversations with Canadians;**
- **outline our initial thinking about building an "analytical framework" for assessing different approaches; and**
- **provide, as background for you, some important information on alternative technical methods for managing used nuclear fuel.**

We hope that in "thinking out loud", and in sharing our early thoughts on the analysis, we will encourage you and many different communities of interest to contribute, so your perspectives and priorities may be integrated into the next phase of our study.

This is only the beginning of an important dialogue. Before we prepare our final submission to the federal government, we will ask you to review, comment and discuss two additional documents – first, our assessment of the options (in 2004); and second, our proposed recommendations and implementation plans (in 2005).

The opportunity for public engagement does not end with the study's submission to the Minister of Natural Resources Canada in late 2005. In considering the implications of the NWMO's recommendations for Canadians, the Minister may consult with the public on the approaches set out in the NWMO study, as considered necessary.

Once the Governor in Council makes a decision on an approach - on the recommendation of the Minister - opportunities for public engagement may continue, including those involving the environmental assessment and licensing processes of regulatory authorities.

THE NWMO MANDATE

In November 2002, the Government of Canada enacted the *Nuclear Fuel Waste Act*. The purpose of the Act is to provide a framework that will enable the Governor in Council, on the advice of the Minister of Natural Resources, to make a decision on the management of nuclear fuel waste that is based on *a comprehensive, integrated, and economically sound approach for Canada.*[1]

Nuclear fuel waste is defined in the Act as irradiated fuel *removed from a commercial or research nuclear fission reactor.* The focus is clearly on **used nuclear fuel**; the NWMO is not asked to address other forms of radioactive waste.

The *Nuclear Fuel Waste Act* compels the nuclear energy corporations who produced the waste to create and fully fund a not-for-profit corporation (NWMO) to study and propose to the Government of Canada approaches for the management of used nuclear fuel, and implement the approach that is selected by Government. The NWMO will then carry out the managerial, operational and financial activities required to implement the long-term management of used nuclear fuel.

Initially, the NWMO has been asked to engage with Canadians to undertake the needed research and reflection that will lead to recommendations on how Canada should proceed with managing used nuclear fuel over the long term.

Specifically, Section 12 (1) of the federal *Nuclear Fuel Waste Act* requires the NWMO to submit to the Minister of Natural Resources Canada:

> *a study setting out*
>
> *(a) its proposed approaches for the management of nuclear fuel waste, along with the comments of the Advisory Council on those approaches; and*
>
> *(b) its recommendation as to which of its proposed approaches should be adopted.*

This study must be submitted within three years of the Act coming into force (which means no later than November 15, 2005).

In proposing approaches for the long-term management of nuclear fuel waste, the *Nuclear Fuel Waste Act (Section 12 (2))* explicitly requires that the NWMO study include – at a minimum – three specific technical methods. Section 12 (2) of the Act requires that:

> *Each of the following methods must be the sole basis of at least one approach:*
>
> *(a) deep geological disposal in the Canadian Shield, based on the concept described by Atomic Energy of Canada Limited in the Environmental Impact Statement on the Concept for Disposal of Canada's Nuclear Fuel Waste and taking into account the views of the environmental assessment panel set out in the Report of the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel dated February 1998;*
>
> *(b) storage at nuclear reactor sites; and*
>
> *(c) centralized storage, either above or below ground.*

It is important to note that the NWMO may also consider other technical methods.

The *Nuclear Fuel Waste Act (Section 12)* outlines additional study requirements. For each approach we include in our study, the Act requires:

- a detailed technical description of each proposed approach and the specification of an economic region for its implementation (the Act defines an 'economic region' as *an economic region described by Statistics Canada in its Guide to the Labour Force Survey, published on January 31, 2000)*. The NWMO study will not propose specific sites;

- a comparison of the benefits, risks, and costs of that approach with those of the other approaches, taking into account the economic region in which that approach would be implemented, as well as the ethical, social and economic considerations associated with that approach;

- an implementation plan setting out – as a minimum - the following:

  (a) a description of activities;

  (b) a timetable for carrying out the approach;

  (c) the means that the waste management organization plans to use to avoid or minimize significant socio-economic effects on a community's way of life or on its social, cultural or economic aspirations; and

  (d) a program for public consultation.

In the course of the study, the NWMO must consult the general public, and in particular aboriginal peoples, on each proposed approach. The study submitted to the Minister must include a summary of the comments received by the NWMO as a result of these consultations.

The Act specifies that the Governor in Council, on the recommendation of the Minister of Natural Resources Canada, shall select one approach for managing nuclear fuel waste from among those set out in the NWMO study.

Further, once the Governor in Council chooses an approach, the NWMO will implement it.

The Act also requires nuclear waste producers – Ontario Power Generation, Hydro-Québec, New Brunswick Power and Atomic Energy of Canada Limited (AECL) – to create trust funds to ensure that money is available to implement the selected approach.

The initial payments required by the Act from the four companies totaled $550 million, to be followed by annual increments of $110 million; these are the resources that the NWMO will use in its implementation phase.

THE CONTEXT

We believe it is important to understand the story of nuclear energy in Canada, both past and present. If we are to design an approach for managing used nuclear fuel that is responsive to Canadian values, we are compelled to reflect on past experiences.[2]

For some, the starting point is the discovery of radioactivity and x-rays. For others, the point of departure is World War II and the atomic bomb. Still, for still others, the story begins in the second half of the 20th century, with the search for peaceful uses of nuclear energy.

These stories are sketched briefly in the boxes accompanying this chapter.

Early Interest in Radioactive Materials – Medical Implications

Although the first photographic effects of ionizing radiation were seen in 1842, more than 50 years would pass before Wilhelm Conrad Roentgen discovered, investigated and named penetrating x-rays, and took the first deliberate x-ray photographs. Within weeks, there were discoveries of beneficial effects in countering disease and reducing pain and inflammation. However, such reports soon gave way to news of serious injury; over a period of time, some 300 early radiation workers were reported to have died due to radiation exposure.

After Marie Curie's discovery of radium-226 in 1898, demand for its use for medical purposes far exceeded the supply. By 1914, the value of an ounce of radium had briefly skyrocketed to five million dollars, sparking exploration for new sources. In the 1930s, a Dene man found a dark and unusual substance near the shores of Great Bear Lake in Canada's Northwest Territories. The rock was passed on to Gilbert Labine, a gold-mine operator in Edmonton, who recognized the sample as pitchblende and in 1933, established the radium/uranium mine at Port Radium as well as a refinery at Port Hope, Ontario. Within a few years, the mine was the largest radium mine in the world. However, by 1940, the demand had all but disappeared and the mine briefly closed.

WW II, The Bomb, The Cold War

Other developments would soon re-activate interest in Port Radium. In 1939, German scientists discovered "nuclear fission" – the ability to break apart the nucleus of a uranium atom to unlock phenomenal amounts of energy – and the race began to create the first atomic bomb. The United States was aggressive in that race but lacked a uranium source. They turned to Canada and in 1942, the Government of Canada purchased the Port Radium mine and became a supplier of uranium for the "Manhattan Project" (the U.S. initiative to create the atomic bomb). At the same time, C.D. Howe created a federal atomic energy research laboratory.

In July 1945, the first atomic bomb was successfully tested in New Mexico. A month later, Hiroshima and Nagasaki, Japan were bombed, bringing an end to World War II. However, the subsequent Cold War and associated nuclear weapons build-up brought a sharp increase in the demand for uranium. By the early 1950s, some 23 uranium mines were operating in Canada; uranium ore ranked as Canada's fourth largest export (behind newsprint, wheat and lumber).

Implications for the Dene

The early phase of radium – and then, uranium – extraction and the creation of the atomic bomb had a lesser-known effect. In the Northwest Territories, the mines were located on the traditional territory of the Dene people. Because of the health concerns raised by the Dene (and the knowledge that uranium from their land fuelled the bombs that hit Hiroshima and Nagasaki), the ethical issue of uranium mines and their link to destructive nuclear power now trouble the Dene. In 1998 a delegation of Dene made an historic visit to Japan to meet with the people of Hiroshima and Nagasaki and express their regret.

Post World War II

Immediately after World War II, Canada played a leading role in advocating non-proliferation. In 1952, U.S. President Dwight Eisenhower delivered his famous "atoms for peace" address to the United Nations, pleading with the world community of nations to set aside the arms race and instead focus on peaceful applications of nuclear energy.

Since that time, many important peaceful uses of nuclear energy have developed in Canada. One significant application has been the generating of electricity through nuclear power. In 1952, Atomic Energy of Canada Limited (AECL) was created to pursue the peaceful use of nuclear power. >

Post World War II (cont'd)

A decade later, AECL, working with Ontario's Hydro-Electric Power Corporation (predecessor to Ontario Hydro and Ontario Power Generation) brought the 25 MW Nuclear Power Demonstration Plant at Rolphton into production. In 1968, the first commercial nuclear power was produced by the Douglas Point reactor, in Kincardine, Ontario. Within 25 years, 22 nuclear reactors would be operating in Canada, generating electricity with a combined capacity of 15,500 MW.

The post-World War II period also saw a significant increase in research into, and applications of, nuclear medicine. Canada's nuclear program has made possible the production of a range of medical isotopes (such as cobalt-60) that are widely used today for preventing, diagnosing and treating disease. AECL's Chalk River Laboratories has been the primary source of radioisotopes for use in nuclear medicine. Today, Canadian reactors produce about 75 per cent of the cobalt-60 used worldwide.

Canada is the world's leading producer of uranium. Saskatchewan uranium accounts for about 30 per cent of global uranium production. Some 85 per cent of Canada's mined uranium is exported – solely for peaceful applications.

The search for peaceful uses of the atom led to a growing use of nuclear power to generate electricity. That in turn, led in the latter part of the 20th century to the accumulation of used nuclear fuel bundles, and the recognition that means had to be found to manage this waste product. The search for a solution began in earnest.

Starting in the early 1970s and for some 20 years, the predominant thinking in the international community regarding the long-term management of used nuclear fuel was that it was best buried and sealed deeply in stable geologic environments. Two chapters in this story are worth highlighting – the Hare Report and the Environmental Assessment Panel led by Blair Seaborn. Each was an important step, ultimately leading to the creation of the NWMO. (See boxes on the next page.) There are many lessons to guide us.

As of November 2003, there were 16 commercial reactors operating in Canada, providing approximately 13 per cent of our nation's electricity. Six other reactors are laid up as their operators focus engineering and technical staff resources on improving the performance of the operating units. As well, there are reactors in Canada that are used for research or other purposes. Additionally, at two locations, AECL has stored nuclear fuel waste from earlier research.

To date, Canada's nuclear power generators and research facilities have produced 1.7 million used fuel bundles.

Used nuclear fuel resulting from these reactors continues to be safely stored in interim storage facilities, pending a decision on the long-term management of used nuclear fuel.

A Focus on Deep Disposal in the Canadian Shield

Deep disposal in the Canadian Shield was first suggested in 1972 by a committee of AECL, Ontario Hydro, and Hydro-Québec; it was subsequently addressed by federal policy in 1974. In 1977, the Department of Energy, Mines and Resources engaged an expert group under the chair of Dr. Kenneth Hare to examine various management methods. The resulting "Hare Report," concluded that deep burial in the stable rocks of the Canadian Shield was the best method. In 1978, the Royal Commission on Electrical Power Planning (the Porter Commission) supported the conclusion of the Hare Report, and in response, Canada and Ontario established the Nuclear Fuel Waste Management Program. AECL was given responsibility for researching and developing "disposal in a deep underground repository in intrusive igneous rock." This method came to be known as the "AECL concept." AECL created the Underground Research Laboratory in Pinawa, Manitoba. Its scientific and technical team quickly gained a world-wide reputation for the quality of its work.

On the regulatory front, the Atomic Energy Control Board (Canada's nuclear regulator at the time) confirmed deep geological disposal as the preferred approach for Canada. In 1987 it published *Regulatory Document R-104, Regulatory Objectives, Requirements and Guidelines for the Disposal of Radioactive Wastes – Long-term Aspects.*

With its emphasis on deep geological disposal, Canada was far from operating in isolation. Across the international community, many nations were investigating a solution offered by deep disposal in a stable geologic environment.

Environmental Assessment and Policy Change

In the late 1980s the idea of a deep disposal repository in the Canadian Shield was examined under the Federal Environmental Assessment Review Process. An Environmental Assessment Panel, chaired by Blair Seaborn, carefully described, discussed and assessed "the AECL concept" in a review of unprecedented scope, duration and cost.

The "Seaborn Panel Report" was produced in 1998. The Panel's four key conclusions were:

- Broad public support is necessary to ensure the acceptability of a concept for managing nuclear fuel wastes.
- Safety is a key part, but only one part, of acceptability. Safety must be viewed from two complementary perspectives: technical and social.
- From a technical perspective, the safety of the AECL concept has been adequately demonstrated for a conceptual stage of development, but not from a social perspective.
- The AECL concept has not been demonstrated to have broad public support. The concept in its current form does not have the required level of acceptability to be adopted as Canada's approach for managing nuclear fuel waste.

The Panel suggested that an acceptable way forward would require a number of steps. They recommended that a comparative review of approaches for managing nuclear fuel waste be undertaken, involving many Canadians. To do this, the Panel recommended developing an ethical and social "assessment framework" through which to undertake a comparative review of the approaches. They emphasized the need for an aboriginal participation process, and to have a comprehensive plan for consulting Canadians broadly.

The Seaborn Panel Report can be found at www.ceaa-acee.gc.ca.

The Federal Response to Seaborn

The federal government responded to the Seaborn Panel Report, and in 2002 brought into force the *Nuclear Fuel Waste Act*, which led to the creation of the Nuclear Waste Management Organization. Reflecting the "polluter pay" principle, the Act also introduced requirements for producers of used nuclear fuel to put aside funds to ensure that adequate resources would be available for managing the used fuel over the long term.

The Port Hope Story of Low-Level Radioactive Waste

The 75-year history of low-level radioactive waste provides a special experience upon which to draw. In 1932, Eldorado Gold Mines Ltd. opened a refinery in Port Hope to produce radium from Port Radium uranium concentrate (yellow cake). Later, the process was adjusted to produce uranium. Significant local contamination occurred, resulting in much public concern. This waste is essentially soil contaminated with radioactive material. The continued public concern led to the formation of the Low-Level Radioactive Waste Management Office to clean up the contamination. In the 1980s, this concern increased: the issue surfaced in the 1984 federal election campaign. In 1988, the federal government initiated an Ontario-wide cooperative siting process to seek a volunteer host community for the Port Hope area wastes.

The process did not result in a long-term solution. Subsequently, in 1997 and 1998-99, the three area municipalities – Hope Township, the Town of Port Hope and the Municipality of Clarington each proposed to the federal government preferred local solutions to the long-term management of low-level radioactive wastes within their communities. These locally-led initiatives resulted, in 2000, in the signing of an agreement in principle involving the Canadian government and the three communities. Each of the three communities would deal with their own waste. The agreement in principle was turned into a legal agreement that was signed in 2001, and the clean-up program began with the environmental assessment process. If approved, facilities will be constructed and clean-up could be completed by 2011.

THE NWMO APPROACH

Our early, informal conversations with Canadians have emphasized that we have no alternative but to responsibly manage the nuclear waste that our society produces. Nuclear power generation has supplied an important part of Canada's electricity supply – but managing the byproduct (used nuclear fuel) is a matter that must be addressed.

In recommending an approach for managing Canada's used nuclear fuel, the NWMO has not been asked to take a position on the broader policy issue of the future role of nuclear energy in Canada. Regardless of the future role of nuclear energy, used nuclear fuel exists today, and there must be a solution for managing the fuel bundles for the long term. The NWMO seeks to recommend a management approach that is robust enough to be sustained regardless of which path Canadians choose for nuclear energy in the future. However, where the NWMO feels that assumptions around future energy scenarios are critical to the assessment of alternatives, these will be reported.

Consistent with the *Nuclear Fuel Waste Act,* and building upon our preliminary discussions with Canadians, the NWMO interprets the concept of a management approach to be broad, encompassing the following components:

- a suggested technical method (or sequence of methods) for storage or disposal;
- the related infrastructure and support systems, including transportation;
- an implementation plan that sets out such things as:
- long-term administrative, legal and financial arrangements;
- key characteristics of the implementing organization;
- details of an independent review mechanism;
- an implementation strategy that will include a timetable for action and the identification of specific tasks and responsible parties;
- principles of site selection;
- how to avoid, or minimize, significant negative socio-economic effects on a community's way of life or on its social, cultural or economic aspirations; and
- a program for public consultation consistent with that approach.

Clearly, any management approach set out in the NWMO study embodies much more than simply a technical method for containing used fuel and its engineering design. Approaches must fully consider ethical, social, cultural, environmental and economic dimensions and they must be sensitive to the impacts that any approach may have on Canadians' way of life and their aspirations. In assuming this stance, the NWMO seeks to earn Canadians' trust and confidence.

As we move into the 21st century, this now 40 year-old issue of used nuclear fuel illustrates the kind of public policy conundrums now facing our society. The scope of the challenge is evident in the experiences of previous studies. Those studies have indicated that the long-term management of used nuclear fuel:

- embodies significant scientific and social complexities and uncertainties;
- requires a deeper understanding of the dynamic interaction amongst nature, technology and society;
- must be addressed through a time horizon that spans thousands of years – a time perspective well beyond many Canadians' comprehension;
- must consider how best to incorporate the perspectives and values of Canada's aboriginal people, and learn from their traditional ecological knowledge; and
- raises discussions of many trade-offs. For example: the current generation's responsibilities versus the rights of future generations; large up-front capital expenditures and low long-term maintenance costs, versus lower up-front capital expenditures and indefinite long-term maintenance costs.

Finding a way forward, in which Canadians have confidence, is only possible through public involvement. The solution must reflect Canadian values and ethical choices. To ensure that result, people from many walks of life need to drive the study process.

The communities of interest for the long-term management of nuclear fuel waste are numerous and diverse. They include but are not limited to:

- residents and representatives of communities where used nuclear fuel is generated and currently stored, as well as communities that might be affected in the future (e.g. communities which might host a nuclear waste management facility or waste transfer station);
- communities which might be located on transportation routes;
- aboriginal people;
- non-profit and non-governmental organizations from society (health, social sciences, energy, environment, faith, professional societies, culture, education, development, civil rights, labour, etc.);
- consumers of energy;
- Canada's youth – who will inherit and live with the decisions we make today;
- business interests;
- the nuclear energy corporations (defined in the *Nuclear Fuel Waste Act* as Ontario Power Generation, New Brunswick Power Corporation, Hydro-Québec and any other body that owns nuclear fuel waste resulting from the production of electricity by means of a commercial nuclear reactor; any successor or assignee; and any assignee of Atomic Energy of Canada Limited.);

- individuals who have an interest in nuclear waste management, and/or who have an area of expertise relevant to the study (whether academic, professional or personal);

- the international community that is undertaking research and seeking acceptable solutions to this problem and with whom Canada has obligations; and

- governments (federal, provincial, local/municipal, and aboriginal).

Canada's nuclear-related policies and actions are not developed in isolation. Canada has played an important international role, both from a scientific and a public policy perspective. Canada's post-World War II decision to set aside its capacity to manufacture nuclear arms, in favour of the peaceful use of nuclear energy and the non-proliferation of nuclear weapons, continues to be a significant feature of our foreign policy. Canada has influenced others and, in turn, is influenced by the world community.

Just as our nuclear policies and actions have not occurred in a vacuum, neither has Canada's decision to undertake a thorough review of alternatives. Internationally, similar reviews have taken place (or are under way) in such countries as Sweden, Finland, the United Kingdom and France.

In the United Kingdom, a review is under way to assess the options for the long-term management of radioactive waste and some other materials.

In France, parliament passed a law in 1991 that will result in the selection of a management method by 2006. That process is now well under way and has included the construction of an underground research laboratory. As well as examining sites and transportation methods, the French are conducting research on long-term storage, deep geological disposal, and partitioning and transmutation.

The NWMO will seek to learn from the experiences of other countries, incorporating the best of their research and expertise.

Later in this document, we describe the way we intend to develop the analytical framework for this study. The framework will build on:

- the questions in the minds of Canadians;

- the advice of experts; and

- the lessons learned from the development of other public policies.

SOME KEY TERMS IN BRIEF

Used Nuclear Fuel
Irradiated fuel from a commercial or research nuclear reactor that has served its intended purpose (for instance, for generation of electricity) and has been removed from the reactor.

Method
A technology, technique, technical process or procedure for handling used nuclear fuel.

Management Approach
A strategy for the long-term care of used nuclear fuel which encompasses a particular technical method or sequence of methods, and all of the conditions necessary for its successful implementation, including societal requirements, related infrastructure, institutional and governance arrangements.

Storage
A method of maintaining used nuclear fuel in a manner that allows access, under controlled conditions, for retrieval or future activities.

Disposal
A method of isolating used nuclear fuel from humanity and the environment that is conclusive and without the intention of retrieval or reuse.

Chapter 2 / Used Nuclear Fuel and How it is Managed

What is used nuclear fuel?
Why is used nuclear fuel hazardous?
Where is used nuclear fuel generated?
How is used nuclear fuel managed currently?
How is used nuclear fuel regulated?

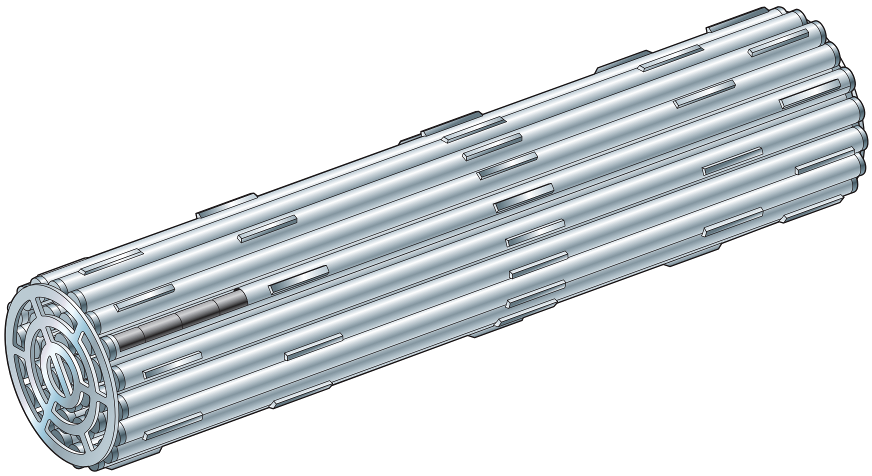


FIGURE 2.1A
Typical CANDU fuel bundle

WHAT IS USED NUCLEAR FUEL?

The volume of waste, its physical and chemical characteristics, and its potential to contaminate the environment all influence the way in which waste is managed. In our society, wastes are generated in many forms, ranging from the high volumes of municipal solid wastes to the more complex waste products arising from industrial processes or the combustion of hydrocarbon fuels.

Used nuclear fuel waste too, has important distinguishing characteristics.

First, a given unit of uranium produces a very large amount of energy; the resulting volume of waste is relatively small. To put the volume into perspective, all of the used fuel bundles created in Canada to date, if stacked end to end, would fill slightly less than five regulation-sized hockey rinks to the top of the boards.

Second, the energy conversion process is contained; that is, under normal circumstances, there is no direct discharge of contaminants to air, surface water or groundwater (though heat is generated). That said, it is important to note that the radioactivity of newly irradiated fuel is great and long-lived. Although the radioactivity hazard diminishes with time, public concern for safety and security is high.

In this chapter, the distinctive characteristics of used nuclear fuel are profiled. These characteristics must be addressed in planning the long-term management of the waste stream.

In a nuclear-powered electricity generating station, heat is produced by fission, which occurs in a fuel bundle when a neutron is absorbed by certain heavy elements (such as uranium-235 or plutonium-239).

In the CANDU system used in Canada, each fuel bundle contains about 19 kg of natural uranium, in the form of high-density uranium dioxide ceramic pellets. These pellets are sealed inside zirconium alloy tubes, about 0.5m long, arranged in a circular array 10 cm in diameter (Figure 2.1A). Heat is removed by passing liquid heavy water over the many bundles in the reactor. In turn, the heavy water coolant passes through boilers which transfer the heat to ordinary water, producing steam. The cooled heavy water is then pumped through the reactor again in a closed loop in order to retain the heavy water. The steam from the boilers drives a turbine generator, producing electricity. (Figure 2.1B)

When an atom is split and neutrons are released, one neutron goes on to split another atom, and so on, keeping the nuclear reaction going. Another 1.3 neutrons (on average) are absorbed by the non-fissionable materials in the fuel and the reactor core. As the process continues, the concentration of fission products increases until their neutron absorption capacity becomes so large that the nuclear reaction begins to be impeded. At this stage, after about 18 months, the fuel is removed both because of the partial depletion of the fissile material as well as the build-up of neutron-absorbing fission products and actinides.[3]

The used fuel contains two types of radioactive nuclides: fission products and actinides.[4]

Fission products are formed when neutrons hit and split uranium-235 atoms. In the splitting process, several dozen different isotopes are formed. The most significant fission products, along with their half-lives (the time required for half of the initial atoms of a given amount of radionuclide to decay) are listed in Table 2.1. Fission products generate large amounts of radiation and heat, so fuel bundles must be handled remotely, and they must be shielded and cooled when first removed from the reactor.

FIGURE 2.1B
CANDU Pressurized Heavy Water Reactor

A. Nuclear reactions in the fuel produce heat
B. Water, flowing through the reactor, transfers heat from the fuel to the steam generator
C. Steam drives the turbines
D. Turbines drive the generators to produce electricity

1. Reactor
2. Steam Generator
3. Reactor Building
4. Turbine
5. Generator
6. Condensor
7. Electricity
8. Cooling Water

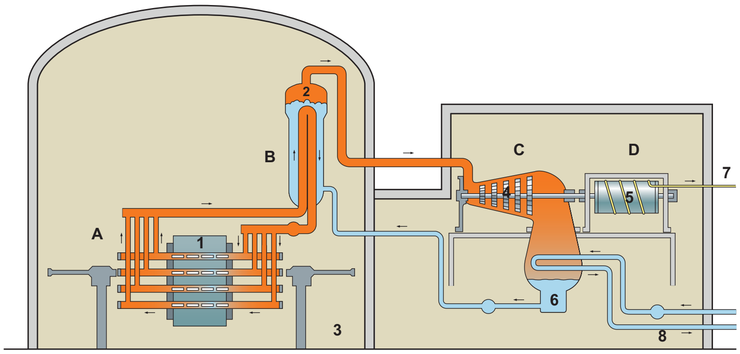


TABLE 2.1
Significant fission products[5]

FISSION PRODUCT	HALF-LIFE (YEARS)
Krypton-85	11
Strontium-90	29
Technetium-99	210,000
Tin-126	210,000[6]
Iodine-129	16,000,000
Cesium-135	2,300,000
Cesium-137	30

Actinides are nuclides of heavy elements in the series beginning with actinium in the periodic table of the elements. Some absorb neutrons, but do not split. The main actinides in used fuel are listed in Table 2.2.

TABLE 2.2
Main actinides in used fuel[7]

ACTINIDE	HALF-LIFE (YEARS)
Uranium-235	710,000,000
Uranium-236	23,000,000
Uranium-238	4,500,000,000
Plutonium-239	24,000
Plutonium-240	6,600
Plutonium -242	360,000
Neptunium-237	2,100,000
Americium-241	460
Thorium-232	1,400,000,000

Activation Products The third and final category of radioactive materials in spent fuel comprises the radioactive isotopes resulting from neutron reactions with materials in the fuel cladding as distinct from the fuel itself. They are called activation products since they arise from non-radioactive materials that have been made radioactive (activated) by fission neutrons. Some of them are shown in Table 2.3.

ISOTOPE	HALF-LIFE (YEARS)
Carbon-14	5,700
Chlorine-36	300,000
Zirconium-93	1,500,000

TABLE 2.3 Activation products in fuel[8]

At the time of removal of the used fuel bundles from the reactor, about 67 per cent of the uranium-235 in the fuel bundles has been consumed. Table 2.4 provides an overall comparison between the composition of fresh and spent CANDU fuel. The major change between fresh and used fuel is the transformation of about two-thirds of the uranium-235 to fission products. There is also an intermediate reaction in which a small amount (less than one per cent) of the uranium-238 absorbs a neutron and transforms to plutonium-239, of which about half subsequently fissions (splits) to produce additional fissile isotopes. About 30 per cent of the energy derived from the fuel bundles is derived from the fissioning of plutonium.

COMPONENT	COMPOSITION OF FRESH FUEL, %	COMPOSITION OF USED FUEL, %
Uranium-235	0.72	0.23
Uranium-236	0	0.07
Uranium-238	99.28	98.58
Plutonium-239	0	0.25
Plutonium-240	0	0.10
Plutonium-241	0	0.02
Plutonium-242	0	0.01
Fission products	-	0.74

TABLE 2.4 Composition of fresh and spent CANDU fuel[9]

FIGURE 2.2
Radioactivity of a used fuel bundle over time (logarithmic scale)

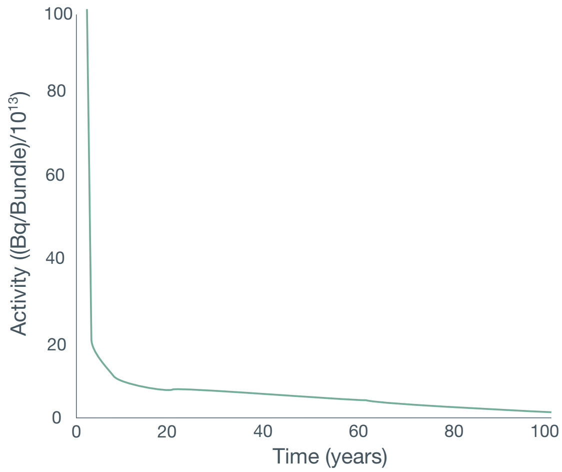
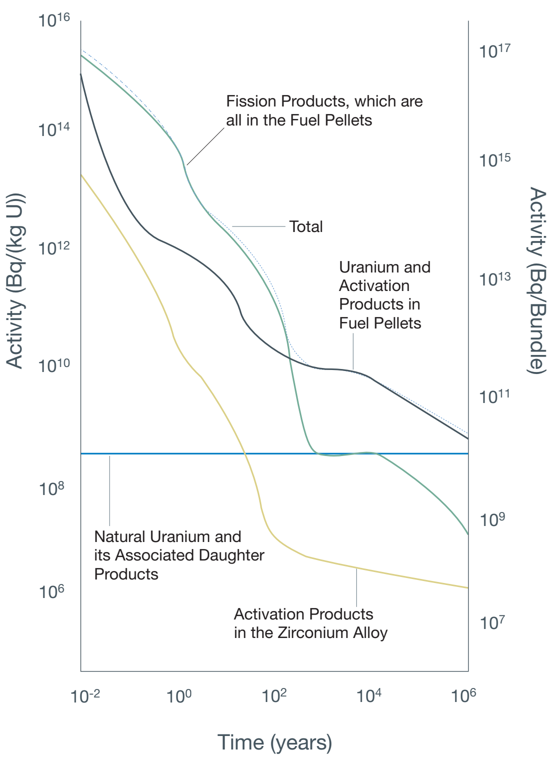


FIGURE 2.3
Total radioactivity per bundle of used fuel (linear scale)



Despite the large amount of energy produced, a relatively small amount of material changes inside the fuel – only about 1.3 per cent of the fuel is modified. Further, the amount of fissile material has changed from 0.7 per cent uranium-235 (in the original fuel) to 0.5 per cent plutonium-239 plus uranium-235 (in the used fuel).

Radioactive decay continues when the used fuel is removed from the reactor, causing emission of radiation and heat at decreasing rates and changing composition over time. Some 350 different isotopes are present, of which about 200 are radioactive.[10]

As shown in Figures 2.2 and 2.3, the level of radioactivity declines rapidly at first, then tails off. Activity declines to that of natural uranium and its associated radioactive decay products after about one million years.[11] These decay characteristics are well-established, having been both observed in nature (radioactive decay has gone on continuously since the earth formed) and modeled theoretically.

WHY IS USED NUCLEAR FUEL HAZARDOUS?

There are three direct hazards associated with used nuclear fuel: radioactivity, heat and toxicity.

Potential Harm from Radioactivity

"Radiation" refers to energy traveling in the form of particles or waves. We encounter radiation every day – as microwaves used to cook food, radio waves, light from the sun, x-rays for medical diagnostic purposes, and gamma rays for medical therapeutic purposes.

Radioactivity is either natural or anthropogenic (that is, man-made).

Sources include radon gas from the earth's crust that is present in the air we breathe, terrestrial radiation from mineral soils, and cosmic radiation from space. Our bodies are also a sourse of radiation from potassium and carbon in the foods we eat. The remaining sources of radiation exposure are man-made. Twenty-three per cent comes from medical technologies including x-rays and gamma-rays. And one per cent can be categorized as "other" – created by things like nuclear generation of electricity.

Radiation is emitted from unstable atoms. These emissions are called "ionizing radiations" because they "ionize" the atoms with which they come into contact. This ionizing process occurs when electrons are removed from (or added to) the electron shell of atoms. When it occurs, this changes the atom's molecular structure. This is why ionizing radiation is potentially hazardous to health – because it can change molecular structures, including the tissue of living organisms.

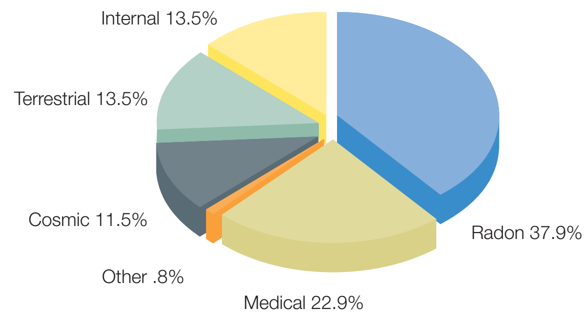
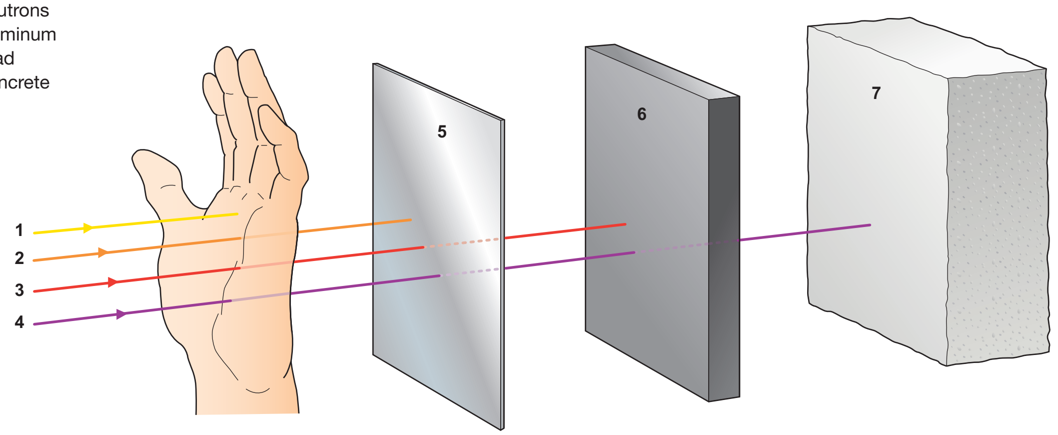


FIGURE 2.4
Sources of average annual radiation exposure in Canada[12]

The form, and amount, of energy emitted determine how far the ionizing radiation can penetrate human tissue, and how much damage it can cause.

Figure 2.5 depicts the five major types of ionizing radiation – gamma rays, x-rays, alpha and beta particles, and neutrons – and what they can penetrate and damage.

FIGURE 2.5
Types of Radiation



As shown, alpha particles and low energy beta particles cannot penetrate human skin. Beta particles can penetrate human skin, but skin is easily shielded from beta particles by a thin aluminum foil. Higher energy radiation – such as neutrons, gamma rays, and x-rays – can penetrate skin, but can be stopped by lead or concrete shielding.

Any living tissue in the human body can be damaged by ionizing radiation. However, the human body can normally withstand the radioactivity we encounter in our daily lives. Natural processes control the rate at which cells grow and replace themselves, and these processes allow the body to repair damaged tissue. Sometimes, however, the damage is too severe or widespread. Exposure to high levels of radiation over the long term can disrupt the body's natural repair processes and permit the uncontrolled growth of cells (commonly known as cancer) and other forms of mutation. Even short-term exposure to very high-levels of radiation can be serious, causing burns and even death.

Potential Harm from Heat

When used fuel bundles are removed from a reactor, they are extremely hot: each bundle gives off more than 25,500 watts of energy - the equivalent of 250 light bulbs (100-watt) in one concentrated bundle. In this initial period, the heat, alone, emanating would cause injury upon direct exposure.

When the fuel bundles are removed, they are placed in water-filled pools where they cool quite rapidly. After about an hour, they emit about 35 per cent of the original heat; after a day, it is 12 per cent; after a year, about .2 per cent. At this time, the heat emanating from one bundle is roughly equivalent to a 60 watt light bulb.

Potential Harm from Toxicity

Radioactivity is, by far, the public's greatest concern related to potential harmful effects of used nuclear fuel. However, in addition to radioactivity, used nuclear fuel has the potential to release chemically toxic elements, including heavy metals.

As the radionuclides end their decay they become stable elements, some of which are toxic. Uranium, for example (the most abundant radioisotope, on a mass basis, in used fuel), has greater chemical toxicity than radiotoxicity. Furthermore, once uranium decays, it becomes lead, which is also toxic.

Other elemental products of radioactive decay are rare, but do exist, and little is known about their environmental behaviour. In addition to the trace elements that appear from the decay of radionuclides, there are a number of trace elements (such as niobium) that are present in used fuel cladding or containment vessels. Eventually, these products of radioactive decay are released into natural geochemical cycles. If these contaminants move into groundwater, surface water, and/or air, and are then taken up by organisms, they can cause harm.

WHERE IS USED NUCLEAR FUEL GENERATED?

In Canada, most used nuclear fuel is the result of electricity generation. In 2002, nuclear energy accounted for 35 per cent of the electricity generated in Ontario, 30 per cent in New Brunswick, and 2.5 per cent in Quebec. Overall, 13 per cent of Canadian electricity generation was nuclear.

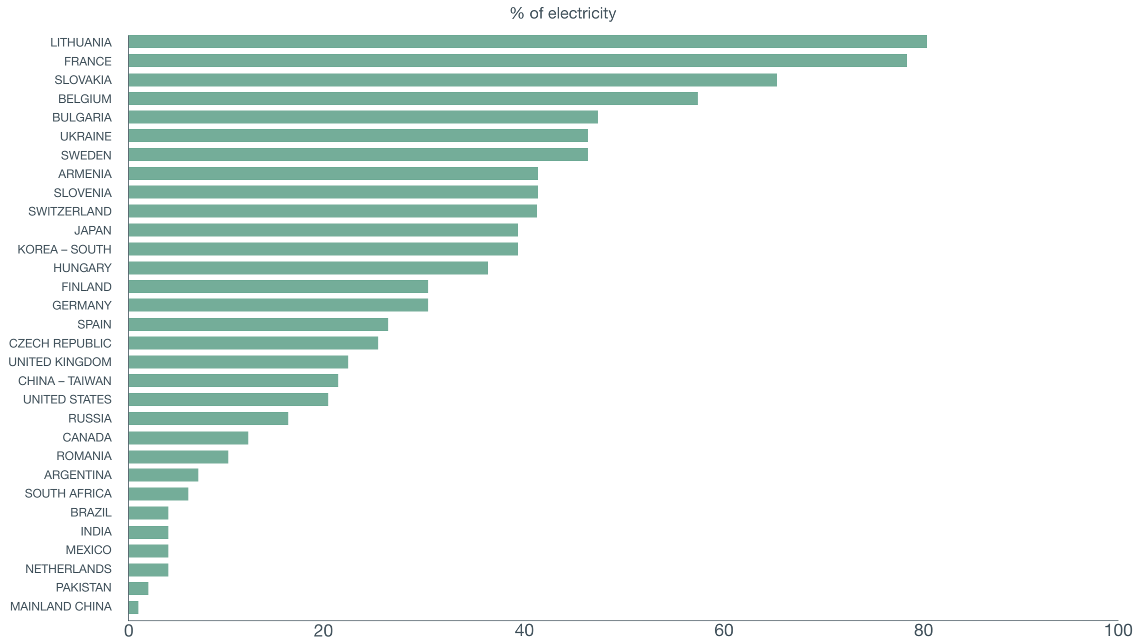
Worldwide, as of July 2003, 439 nuclear power plants accounted for 16 per cent of the world's electricity generation. Another 29 nuclear power plants were under construction in India, China, Japan and Ukraine. And, an additional 25 were approved globally, including 12 in Japan and eight in South Korea with funds in place to proceed.

Figure 2.6 provides a summary of each country's nuclear share of electricity generation in 2002.

In Canada, in addition to commercial nuclear reactors for electricity generation, we also have research reactors and reactors dedicated to producing isotopes for medical purposes. Figure 2.7 identifies the location of Canadian nuclear reactor sites.

Tables 2.5 and 2.6 describe the licensed reactors in Canada. As of December 31, 2002, 22 commercial CANDU reactors were licensed and as of March 31, 2002, there were 11 operating research reactors.

FIGURE 2.6
Nuclear share of Electricity Generation by country[13]



HOW IS USED NUCLEAR FUEL MANAGED RIGHT NOW?

All used nuclear fuel in Canada is currently in "interim storage" pending resolution of the long-term management issue. When used fuel is removed from the reactor, it is initially placed in water-filled pools, where it remains until the heat and radioactivity decline. After approximately seven to ten years, the bundles can be transferred to dry storage at the reactor sites. Dry storage containers are designed, typically, to last 50 years.

All countries place used nuclear fuel in water filled pools immediately following removal from the reactor. The amount of time the fuel remains in the water pools and the location of the storage facility varies by country. As in Canada, some countries keep the fuel at the reactor site either in the water-filled pools, or transfer them to dry storage containers for interim storage – Finland and most utilities in the United States follow this practice. A few countries (e.g. Switzerland, France, Sweden) ship used fuel to a centralized facility, or away from reactor site for interim storage, which can involve either pools or dry storage. Some other countries ship the used fuel to reprocessing facilities. The reprocessed fuel is then returned to the country of origin along with the high-level waste that is produced.

In Canada, used nuclear fuel is safely stored, meeting licence provisions of the Canadian Nuclear Safety Commission (CNSC). Nuclear fuel waste management facilities in Canada are regulated and licensed by the CNSC. The facility operators require licences for the construction, operation and decommissioning of any nuclear facility. A prerequisite for licensing a new or expanded nuclear waste management facility is the approval of an Environmental Assessment (EA) conducted in compliance with the requirements of the Canadian Environmental Assessment Act. The CNSC monitors all activities of the waste management facilities to ensure that the operations pose no undue risks to people or the environment. In addition, under Canada's participation in the nuclear non-proliferation treaty, nuclear fuel waste management facilities are monitored by the International Atomic Energy Agency, to ensure that all used fuel is accounted for.

The location of Canada's used fuel storage facilities are shown in Figure 2.7. The quantities of used nuclear fuel are listed and described in Table 2.7.

The inventory of 1.72 million spent fuel bundles as of the end of 2002 (shown in Table 2.7), will increase in the future. Estimates of future used fuel bundles vary depending upon a number of factors including reactor capacity, maintenance schedules, refurbishment and decommissioning. The estimated future inventory of 3.6 million used fuel bundles (shown in Table 2.8) is based on information submitted by nuclear energy corporations to the CNSC.

The NWMO will update the projected inventory of used fuel bundles in its subsequent Discussion Documents to reflect any change in developments during the study period.

FIGURE 2.7
Nuclear reactor sites and used fuel storage facilities in Canada

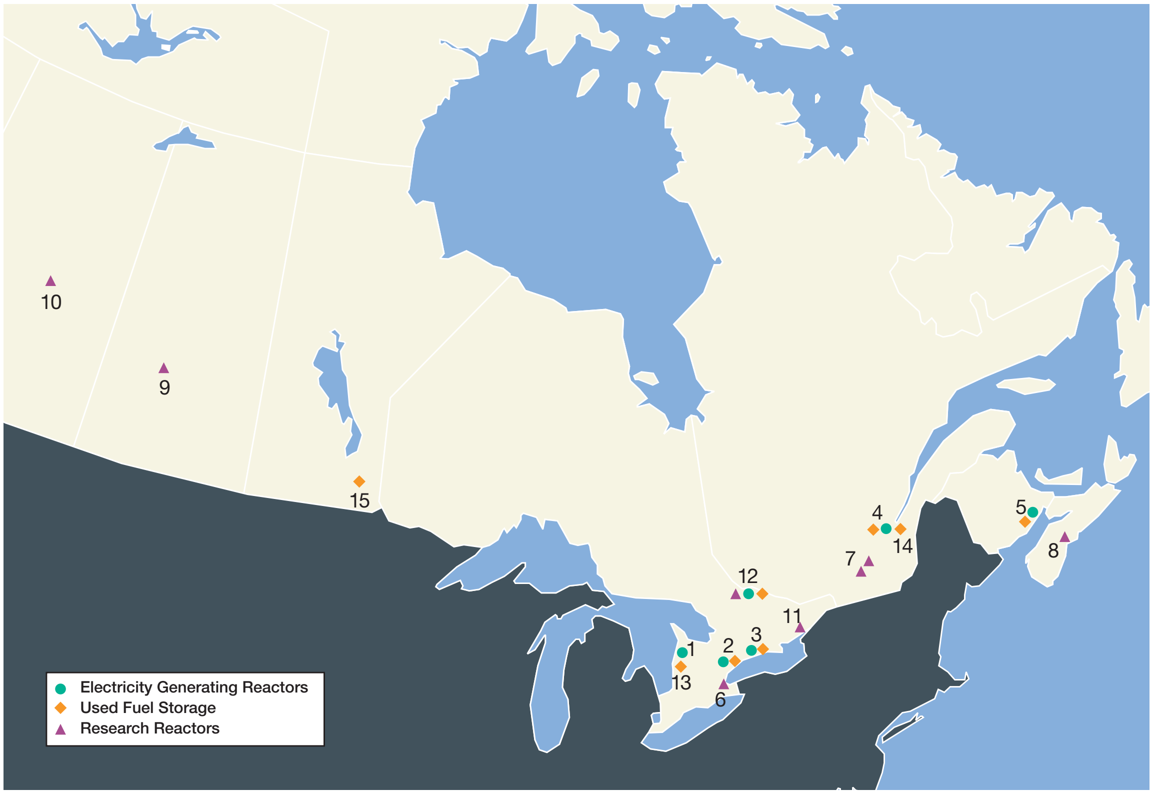


TABLE 2.5
Nuclear generating stations in Canada.[14]

SITE	REACTORS	OPERATOR	LOCATION *(SEE MAP ABOVE)*
Bruce-A	4 x 825 MW	Bruce Power Inc.	Kincardine, ON *(1)*
Bruce-B	4 x 915 MW	Bruce Power Inc.	Kincardine, ON *(1)*
Pickering-A	4 x 540 MW	Ontario Power Generation	Ajax-Pickering, ON *(2)*
Pickering-B	4 x 540 MW	Ontario Power Generation	Ajax-Pickering, ON *(2)*
Darlington	4 x 880 MW	Ontario Power Generation	Bowmanville, ON *(3)*
Gentilly-2	1 x 635 MW	Hydro-Québec	Trois-Riviéres, QC *(4)*
Point Lepreau	1 x 635 MW	New Brunswick Power	Saint John, NB *(5)*

TABLE 2.6
Research and isotope-producing reactors in Canada.[15]

LICENSEE	REACTORS	LOCATION *(SEE MAP ABOVE)*
McMaster University (Pool-type research reactor)	5 MWt	Hamilton, ON *(6)*
Ecole Polytechnique (SLOWPOKE-2)	0.02 MWt	Montreal, QC *(7)*
Ecole Polytechnique (Subcritical Assembly)	0 MWt	Montreal, QC *(7)*
Dalhousie University (SLOWPOKE-2)	0.02 MWt	Halifax, NS *(8)*
Saskatchewan Research Council (SLOWPOKE-2)	0.02 MWt	Saskatoon, SK *(9)*
University of Alberta (SLOWPOKE-2)	0.02 MWt	Edmonton, AB *(10)*
Royal Military College of Canada (SLOWPOKE-2)	0.02 MWt	Kingston, ON *(11)*
AECL (Maple 1)	10 MWt	Chalk River, ON *(12)*
AECL (Maple 2)	10 MWt	Chalk River, ON *(12)*
AECL (NRU)	135 MWt	Chalk River, ON *(12)*
AECL (ZED-2)	0.0002 MWt	Chalk River, ON *(12)*

MWt represents thermal power, which applies to non-power reactors

TABLE 2.7
Storage of used nuclear fuel as of December 31, 2002[16]

STORAGE LOCATION *(SEE MAP OPPOSITE)*	LICENSEE	FUEL BUNDLES IN REACTOR	USED-FUEL BUNDLES IN WET STORAGE	USED-FUEL BUNDLES IN DRY STORAGE	TOTAL FUEL BUNDLES
ONTARIO					
Bruce A *(1)*	Bruce Power Corporation	0	354,567	0	354,567
Bruce B *(1)*	Bruce Power Corporation	24,679	356,519	0	381,198
Pickering *(2)*	Ontario Power Generation	36,756	393,690	99,106	529,552
Darlington *(3)*	Ontario Power Generation	24,960	211,932	0	236,892
Douglas Point *(13)*	AECL	0		22,256	22,256
Chalk River Laboratories *(12)* (used fuel from Rolphton Nuclear Power Demonstration)	AECL	0		4,853	4,853
QUEBEC					
Gentilly 1*(14)*	AECL	0	0	3,213	3,213
Gentilly 2 *(4)*	Hydro-Québec	4,560	37,181	48,000	89,741
NEW BRUNSWICK					
Point Lepreau *(5)*	New Brunswick Power	4,560	40,482	52,920	97,962
MANITOBA					
Whiteshell Laboratories *(15)* (used fuel from Douglas Point and non-standard waste)	AECL	0		360	360
TOTAL		95,515	1,394,371	230,708	1,720,594

TABLE 2.8
Estimated future used fuel inventory[17]

RESPONSIBLE	FACILITIES WHERE USED FUEL BUNDLES ARE LOCATED	NUMBER OF USED FUEL BUNDLES AS OF 31 DECEMBER 2002 (FROM TABLE 2.7)	ESTIMATED FUTURE USED FUEL BUNDLES
OPG	Bruce A	354,567	3,300,000 (1)
	Bruce B	381,198	
	Pickering	529,552	
	Darlington	236,892	
AECL	Chalk River Laboratories	4,853	4,853 (2)
	Douglas Point	22,256	22,256 (3)
	Whiteshell Laboratories	360	360 (3)
AECL	Gentilly 1	3,213 (3)	3,213 (3)
Hydro-Québec	Gentilly 2	89,741	133,000 (4)
NB Power	Point Lepreau	97,962	111,480 (5)
TOTAL		**1,720,594**	**3,575,162**

(1) Reference - OPG Report W-CORR-00531-0052, "Revised Plan and Cost Estimates for Management of Used Fuel", October 2002, submitted to the CNSC.
This report provides OPG's projected total inventory of 3.3 million bundles assuming all of the reactors operate for 40 years.
(2) This is a research facility that no longer produces used CANDU fuel.
(3) These are decommissioned facilities that no longer produce used CANDU fuel.
(4) Reference – Attachment to Hydro-Québec Document H08-1374-003, "Preliminary Decommissioning Plan for G-2 Nuclear Generating Station", April 2001, submitted to the CNSC. This document refers to an estimate of 133,000 bundles to be produced by 2013. The assumed Gentilly-2 station design life is 30 years. No decision has been taken yet regarding the refurbishment of Gentilly-2. If the refurbishment is approved, the operation of Gentilly-2 would be extended and the estimated bundles will be revised accordingly.
(5) Reference - Attachment 1 of August 2003 letter from NB Power submitted to the CNSC. The attachment to this letter refers to an irradiated fuel inventory of approximately 111,480 bundles at the end of NB Power's current Power Reactor Operating Licence (March 31, 2006). If the operation of Point Lepreau is extended beyond March 2006, the estimated bundles will be revised accordingly.

HOW IS USED NUCLEAR FUEL REGULATED?[18]

The legal and administrative arrangements governing nuclear energy have evolved considerably since the industry's inception immediately after World War II. Today, Canada has a relatively mature legal regime. The industry is regulated both through laws of general application and through specially-focused regulations, policies and licence provisions.

Canadian Nuclear Safety Commission (CNSC)

The Canadian Nuclear Safety Commission (CNSC) is the regulatory body established by the federal government to license nuclear facilities and to regulate the use of nuclear energy and materials to protect health, safety, security and the environment and to respect Canada's international commitments on the peaceful use of nuclear energy"[19].

The CNSC is best described as the nuclear energy and materials "watchdog" in Canada. The CNSC is responsible for regulating nuclear power plants, nuclear research facilities and many uses of nuclear materials, including the use of radioisotopes for the treatment of cancer, and the operation of uranium mines and refineries.

In May, 2000 the CNSC replaced the Atomic Energy Control Board (AECB) as a result of the promulgation of the *Nuclear Safety and Control Act*[20] and amendments to the *Atomic Energy Control Act* (which was renamed the *Nuclear Energy Act*[21]). The CNSC mandate involves:

- Regulating the development, production and use of nuclear energy in Canada;
- Regulating the production, possession and use of nuclear substances, prescribed equipment and prescribed information;
- Implementing measures respecting international control of the use of nuclear energy and substances, including measures respecting the non-proliferation of nuclear weapons; and
- Disseminating scientific, technical and regulatory information concerning the activities of the CNSC.

All current nuclear facilities – including provisions for nuclear waste management – must be licensed by the CNSC. Presently, all facilities meet or exceed regulatory requirements.

The CNSC requires licence applicants to conduct detailed analyses of the anticipated effects on the environment, and on human health, safety and security of the proposed licensed activity. It also requires applicants to conduct a public information program that provides this information to persons living in the vicinity of the site in a clear and understandable manner.

As part of the review process, the CNSC evaluates the detailed submissions of the applicant, including the public information program. In addition, and to facilitate openness and transparency, the CNSC makes decisions on the licensing of major nuclear facilities through a public hearing process. The CNSC notifies and encourages individuals and organizations to attend public hearings, and to make submissions orally or in writing. Advance notice of the hearings is published in newspapers and notice of hearings and meetings is posted on the CNSC website (www.nuclearsafety.gc.ca). A detailed record of proceedings, including the reasons for the decision of the Commission, is made available to the public shortly after the proceedings.

The CNSC also administers the *Nuclear Liability Act*, including designating nuclear installations, prescribing basic insurance to be carried by the operators, and administering supplementary insurance coverage premiums for those installations.[22]

Policy Framework

In 1996, the federal government published its Policy Framework for Radioactive Waste. The framework was meant to lay the ground rules and define the role of government and waste producers for the approach to waste management that was anticipated in the Seaborn Panel Report. Three principles were defined:

- the federal government will ensure that radioactive waste disposal is carried out in a safe, environmentally sound, comprehensive, cost-effective and integrated manner;
- the federal government has the responsibility to develop policy, to regulate, and to oversee producers and owners to ensure they comply with legal requirements, and meet their funding and operational responsibilities; and
- the waste producers and owners are responsible, in accordance with the principle of "polluter pay", for the funding, organization, management and operation of disposal and other facilities required for their wastes, recognizing that arrangements may be different for nuclear fuel waste, low-level radioactive waste and uranium mine and mill tailings.

These principles were later re-iterated in the *Government of Canada Response to Recommendations of the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel*[23]. The Response provided further direction for federal nuclear fuel waste management policy, leading to the implementation of the 2002 *Nuclear Fuel Waste Act* and the requirement for the companies which produce used nuclear fuel to:

- establish a waste management organization (nuclear waste management agency) as a separate legal entity to provide recommendations to the Government of Canada on the long-term management of used nuclear fuel; and
- establish segregated funds to finance the long-term management of used fuel.

In addition, the Act directs the NWMO to establish an Advisory Council whose comments on the waste management organization's study, and reports, are made public.

The NWMO is required to submit to the Minister of Natural Resources, by November 2005, proposed approaches for managing used nuclear fuel, along with comments of the Advisory Council, and a recommended approach.

The Act authorizes the Government of Canada to decide on the approach. The Government's choice will then be implemented by the NWMO, subject to all of the necessary regulatory approvals.

In summary, Table 2.9 lists the key federal legislation that provides the overarching legal and administrative framework governing used nuclear fuel in Canada.

TABLE 2.9
Key federal legislation governing used nuclear fuel in Canada[24]

LEGISLATION	SIGNIFICANCE
Legislation (and related regulations) Related to Nuclear Substances	
Nuclear Energy Act, 1997	Replaces the *Atomic Energy Control Act.*
Nuclear Safety and Control Act, 1997	Establishes the CNSC to replace the AECB.
Nuclear Liability Act, 1997	Creates obligation to prevent injury to health, or damage to property, from nuclear material at the facility (or while it is being transported). Limits liability to $75 million. Allows Parliament to enter into a reciprocal agreement with other countries for compensation for damage elsewhere caused by a nuclear incident in Canada.
Nuclear Fuel Waste Act, 2002	Establishes the NWMO; requires financing mechanism to fund nuclear fuel waste management over the long term.
Laws (and regulations) of General Application	
Canadian Environmental Assessment Act, 1992	Requires an environmental assessment of nuclear waste management facilities.
Transportation of Dangerous Goods Act, 1992	Nuclear substances are classed as “dangerous goods” and fall under this Act and its regulations, unless exempted by the *Packaging and Transport of Nuclear Substances Regulations under the Nuclear Safety and Control Act.*
Canadian Environmental Protection Act, 1999	Governs environmental aspects of inter-provincial shipments of hazardous wastes and recyclable materials.

The transportation of used nuclear fuel is a particular concern. To transport used nuclear fuel, a proponent (the transporter) must obtain a licence that contains, in addition to the information required by the Packaging and Transport of Nuclear Substances Regulations of the *Nuclear Safety and Control Act*, a detailed transportation security plan. The information required for the plan includes, but is not limited to, the following:

- a threat assessment;
- proposed security measures; and
- arrangements for a response force.

Before a licence is issued, the security plan submitted with the licence application is reviewed by CNSC staff in the Security and Emergency Response Division to ensure compliance with the regulations and a "best-practices" approach to the security arrangements.

Although Canada's constitutional division of power confers the authority to regulate nuclear energy to the federal government, it does not exclude provincial and territorial authority to regulate related matters within the provincial domain. A full discussion of this topic, as well as greater detail of the federal laws and regulations, may be found in NWMO Background Paper 7.3 *"Status of the Legal and Administrative Arrangements for High-level Radioactive Waste Management". (See Appendix 3.)*

Canada also participates actively in the conventions and standards development led by the United Nations International Atomic Energy Agency (IAEA). The IAEA serves as the global focal point for nuclear cooperation, assisting member countries in planning for and using nuclear science and technology for various peaceful purposes.

Among other roles, the IAEA develops nuclear safety standards and, based on these standards, promotes the achievement and maintenance of high levels of safety in applying nuclear energy, as well as in protecting human health and the environment against ionizing radiation.

The IAEA also verifies, through its inspection system, that member countries comply with their commitments under the Treaty on the Non-Proliferation of Nuclear Weapons, to use nuclear material and facilities for peaceful purposes only.

Canada is involved in a number of international agreements that address nuclear waste management, including:

- The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management;
- The Convention on the Physical Protection of Nuclear Material;
- The Convention on Nuclear Safety;
- The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter;
- The Antarctic Treaty; and
- The Treaty on the Non-Proliferation of Nuclear Weapons.

The above treaties, conventions and agreements provide a general framework of considerations within which Canada is committed to operate.

Chapter 3 / An Analytical Framework

FOUNDATIONS

From its beginning, the NWMO has committed to "develop collaboratively with Canadians a management approach for the long-term care of used nuclear fuel that is socially acceptable, technically sound, environmentally responsible and economically feasible."[25]

This mission statement derives from two sources. First, it draws directly from the *Nuclear Fuel Waste Act*, which states:

Each proposed approach must include a comparison of the benefits, risks and costs of that approach with those of the other approaches, taking into account the economic region in which that approach would be implemented, as well as ethical, social and economic considerations associated with that approach.

Second, the NWMO's mission statement reflects our commitment to use "sustainability," as a foundation for our deliberations.

In this section, we set out our early thinking regarding the analytical framework that will be used to guide our assessment of alternative management approaches.

The analytical framework is built on the basis of input from a broad diversity of communities of interest. It consists of:

- a series of questions to be asked and answered for each management approach, and
- a process for undertaking a comparative assessment of alternatives.

Below, we describe how we are developing the framework. We also list some preliminary questions, to spark dialogue and discussion. The NWMO looks forward to your feedback on whether these questions capture the key issues. With more input, the questions will be refined.

In our conclusions, we describe "next steps" in developing and applying the analytical framework, as well as the questions that lie at its core. By asking the right questions, we will define, for the purposes of this study, what we mean by "socially acceptable, technically sound, environmentally responsible and economically feasible." Finally, by inviting comment from the public, we will ensure that these questions capture the interests and values of Canadians.

FRAMEWORK DEVELOPMENT

In developing an analytical framework, the challenge is to ensure that it is driven by the values of Canadian society as a whole, as well as by those communities of interest who have chosen to engage on this issue.

We are particularly concerned that the perspectives of aboriginal peoples are brought forward and reflected in the study. We believe that traditional knowledge can guide and inform us as we develop our processes and approach to analyzing the options.

The approach embraced by the NWMO in developing and implementing the framework is aimed at ensuring a transparent and inclusive process for:

- shaping the questions that are posed and answered; and
- guiding how the relative importance of factors is assigned, and trade-offs are addressed, in the overall comparative assessment.

Early in our mandate, we initiated a range of activities in order to elicit direction from Canadians for determining the questions that we should ask in comparing the different management approaches.

The NWMO:

- convened early conversations with Canadians, to begin to appreciate expectations both for process and the issues to be explored in our study;
- commissioned a series of papers; and
- convened workshops to initiate some focused discussion on specific topics.

In the discussion below, we highlight some of the key insights that emerged from these discussions and early explorations of concepts.

Early Conversations About Expectations and Learning From the Past

One of the first things the NWMO did was to hold some early conversations with Canadians about initial expectations for the process, and the range of issues requiring study.

The NWMO initiated face-to-face conversations with more than 250 individuals and representatives of organizations at local, provincial, national and international levels. These included representatives of aboriginal organizations, nuclear power plant workers, youth, residents of nuclear power plant communities, environmental groups, industry experts, faith communities, business, government agencies and parliamentarians.

Public opinion research was conducted– first with 14 focus groups in seven centres across Canada in 2002, then a nation-wide telephone survey of 1,900 Canadians was conducted in early 2003.

Both in the face-to-face conversations and in the public opinion research, Canadians highlighted a need for:

- multi-party evaluation, including scientists, engineers, communities with nuclear waste and the public;
- inclusion and consideration of a diversity of views; and
- paying close attention to those Canadian regulatory standards already in place, and the evolving regulation and standards around the world.

We also carefully reviewed the substantial dialogue which took place in the 1990s regarding the deep geological disposal concept proposed by AECL and related Seaborn Panel hearings.

Canadians and experts raised a number of questions and areas of concern about the concept which might be equally applied to any of the used nuclear fuel management approaches examined currently:

- impacts on human health and safety;
- scientific risks and uncertainties;
- risks associated with transporting used nuclear fuel;
- adequate regulation and oversight;
- fairness and equity for future generations;
- adequate funds for proper implementation and operation;
- how this policy decision relates to other policy decisions, for example, the future of nuclear energy; and
- aboriginal values as part of decision-making.[26]

The NWMO understands that it is important to address all of these areas of concern.

Envisioning the Future

Over the past several decades, formal techniques have emerged for thinking about the future in ways that strengthen current decision-making. Taking advantage of these techniques is particularly important for the issue of managing used nuclear fuel because of the long time frames over which used nuclear fuel remains hazardous to people and the environment. Decisions we make today will have repercussions for generations to come and to the best of our ability we have to alert ourselves to these repercussions in our deliberations.

Although we cannot know what future societies will look like, we can try to anticipate what they may look like by envisioning a broad range of possibilities. This is the approach taken by formal scenarios technique. Using the insight of a team of individuals drawn from many interests, a range of futures is designed, each of which is equally plausible according to what we know today. Some of these futures may be more desirable than others but in this effort, we are not setting out to design a future that we want or to predict the future.

In this exercise, various futures were used to develop a sense of what kind of conditions would have to be faced in managing used nuclear fuel over the long term. Doing this helps to strengthen our understanding of the needed management approach.

In order to undertake the scenarios analysis, the NWMO convened a Scenarios Team consisting of 26 individuals drawn form a range of interests and locations across Canada. Four workshops of several days each were held. This major initiative of the NWMO in the early stages of the study reflects amongst other things, the importance attached to fulfilling our responsibility to future generations in as robust and transparent manner as possible.

The Team's deliberations began with a brainstorm of all the key factors and drivers that influence the nature of used nuclear fuel and the conditions in which it will be managed. To span the kind of time frame needed, the group explored four time horizons: 25 years (1 generation) into the future, 175 years (7 generations) into the future; 500 years (20 generations) into the future and 10,000 years (400 generations) into the future.

After reviewing the dozens of factors and drivers, two sets were identified that seemed to be the most important as well as the most uncertain. One of these sets relates to the "magnitude" of the challenge presented by the used nuclear fuel issue. The second set relates to the social, economic, and environmental well-being of society.

By taking this approach, the Scenarios Team generated a range of different but plausible futures. In some of these, the magnitude of the problem presented by used nuclear fuel is great, in others it is not. Thus the scenarios illustrate a range of different conditions related to, for example: electricity demand (high or low), the role of nuclear energy in providing power (great or little), state of the economy (robust and healthy or stagnant and declining); technologies available to treat used nuclear fuel (present or not).

In considering social, economic, and environmental well-being the team developed different scenarios where that well-being varies tremendously; for example: the occurrence or not of war or peace; disease or health; many or few natural disasters; a healthy state of the environment or one that is unhealthy; a wealthy society or poor; strong and respected social and government institutions or weak and disrespected institutions and so forth.

In all, the group described four detailed scenarios for the 25 year timeframe, 12 much less detailed scenarios or "scenarioettes" for the 175 year timeframe, 16 sets of conditions for the 500 year time frame that came to be called "end-points", and a number of simple "what-ifs" for the 10,000 year timeframe.

Throughout the development of these various perspectives on how the future might unfold, conditions were highlighted that would influence today's decision that Canada faces about the choice and design of a management approach for used nuclear fuel. These conditions were then captured in questions to be asked of each alternative management approach.

Full details of the scenarios that were developed are available in the Scenarios Report[27] on the NWMO website. We urge you to review this report, reflect on the contents from your own perspective, and share with us your insights.

Exploring Concepts

The NWMO commissioned a series of papers (see Appendix 3) to explore certain specific concepts which are often used to identify and clarify solutions to difficult public policy issues.

Our intent was to identify lessons from each concept, and their principles, that might be applied to our study. The concepts explored in these papers also relate to many issues and challenges raised by Canadians during our early conversations. Some of those key lessons are highlighted below. We invite you to review the full papers on the NWMO website.

Sustainable Development – Focusing on Human and Ecosystem Well-being

Sustainable development was popularized in the 1987 Report of the World Commission on Environment and Development (the Brundtland Commission). It is a concept that guides decision-makers toward choices which are economically, environmentally and socially sustainable.

Sustainable development calls for decisions to be made in a way that ensures both human and ecosystem well-being are maintained (or improved) over the long-term. Maintaining or improving one, at the expense of the other, is not acceptable from a sustainability perspective, because the foundation for life is undermined when only one factor is considered.

Key considerations for elements of an approach, and building blocks which might be adopted in the study, are:

- intergenerational equity;
- integrated decision making;
- living off income rather than capital; and
- equivalent consideration of social, environmental and economic factors.

In applying the concept of sustainable development to the issue of managing nuclear waste, 10 potential questions surfaced in the work commissioned by the NWMO [see side bar opposite].

Risk and Uncertainty – Need for Partnerships of Experts and Citizens

"Risk" and "uncertainty" are important concepts in assessing management approaches for used nuclear fuel.

First, used nuclear fuel is hazardous. It must be isolated from humans and the environment, or managed for a very long period of time.

Second, although much is known about nuclear chemistry, radioactivity and how to manage it, scientific and technical experts cannot predict with complete certainty how any management approach will perform over the many thousands of years required to contain and manage potential releases because data do not exist over this time period.

Similar to many other difficult social issues, on this issue we are faced with making a decision in the face of potentially significant uncertainties.

With so many sources of risk and scientific, technical and societal uncertainty concerning the management of used nuclear fuel, stakeholders and citizens as well as experts must be involved.

Precautionary Approach – A Change in the Treatment of Scientific Evidence

The precautionary approach, or precautionary principle, has become an ever-more prominent feature of the regulatory debate on environmental and health threats, and of associated national and international legislation. In the face of risk and uncertainty, the precautionary approach is potentially useful in making decisions.

In this approach, scientific and technical evidence and analysis remain absolutely essential, but are not considered sufficient for decision-making, because many difficult-to-quantify risks and hazards may be missed.

Key themes in this approach include:

- 'prevention is better than cure';
- 'irreversible' effects should be avoided; and
- the interests of future generations should be respected.

Adopting the precautionary approach calls for interdisciplinary and pluralistic appraisal of the risks and benefits of the different management approaches. It requires the full participation of stakeholders and the affected public.

Questions Arising from Sustainable Development

1. **Engagement.** Is there a commitment to processes that engage the community? Are those processes designed and implemented to ensure all affected communities (including vulnerable or disadvantaged groups) have the opportunity to participate? Are those processes understood?
2. **People.** Will the project/operation lead (directly or indirectly) to maintaining (or, preferably, improving) people's well-being? If the eventual site decision results in one or more communities acting as hosts for new facilities, this implies those communities will be assisted in developing effective, representative community organizations. It includes developing appropriate standards for worker health and safety, as well as that of the host community.
3. **Environment.** Will the project or operation lead (directly or indirectly) to maintaining or strengthening the integrity of biophysical systems? Will the systems continue to support the well-being of people and other life forms?
4. **Economy.** Is the financial health of the project assured? This will entail the preparation of proper cost/benefit analyses of the project itself.
5. **Traditional and Non-market Activities:** Will the project or operation contribute to the long-term viability of traditional and non-market activities in the host community?
6. **Institutional Arrangements and Governance.** Are institutional arrangements and systems of governance in place? Do they provide certainty and confidence that government, companies, communities, and residents have (or will have) the capacity to address project or operational consequences? Will this capacity exist, and continue to evolve, in the foreseeable future?
7. **Overall Integrated Assessment and Continuous Learning.** Has an overall evaluation of all reasonable alternatives been made? Is there a means of periodically re-evaluating reasonable alternatives and reasonable project configurations?
8. **Security.** Does the method of dealing with radioactive waste contribute to North American security?
9. **Ethics.** Is the study process itself being carried out in an ethical fashion?
10. **Risk and Precaution.** Do we understand the risks of each of the possible solutions?

Adaptive Management – Building in Flexibility and Reversibility to Learn from Experience

The concept of "adaptive management" was first advanced as a way to improve people's understanding of valued ecosystems over time, in the context of natural resource policy making.

It is an approach to decision-making in the face of incomplete knowledge and of uncertainties; it involves treating policies as opportunities for learning, recognizing that surprises are likely, and being prepared to use the new information gained from these.

With this approach, "learning from experience" becomes an explicit objective; much attention is devoted to setting up instruments to detect and study unpredicted events over time, as a means of limiting their unwelcome effects.

"Flexibility" and "reversibility" are important values in this approach, although success depends on favourable social conditions and a society that learns from this kind of experimentation, acts upon those lessons, and transfers those lessons to future decision makers.

Security – Need to Secure the Used Fuel and the Management Processes

The attacks of 9/11 and the resulting focus on terrorism have heightened people's concerns about the security of nuclear facilities and materials. A security approach:

- ensures the materials are protected from diversion, attack and accident; and
- maintains and secures the process and infrastructure that we, as Canadians, put in place to manage nuclear waste.

Such a security approach should consider:

- potentially harmful effects from violent and non-violent events; and
- threats to people (the individual and the nation) and the environment.

The effort to ensure security for both the used fuel and its management process requires partnership-based solutions and a dialogue on what is best for the individual citizen.

Alternative Perspectives

Broad questions and requirements are also being identified through commissioned papers and/or specialized workshops in a number of expert knowledge areas. These include:

- ethics;
- traditional aboriginal knowledge;
- environment;
- communities hosting management facilities;
- science and technology;
- finance and law; and
- international best practice.

These alternative perspectives were identified in the first phase of the NWMO's dialogue "Conversations About Expectations." We invite you to review the complete reports on the NWMO website.

Environment

In mid-September 2003 a workshop was held to discuss the environmental aspects of used nuclear fuel. Eleven experts were drawn from business and industry, academia, government and the not-for-profit sector (See Appendix 1). The discussion and suggestions focused on three themes.

- Whatever proposal is recommended, long-term monitoring of environmental effects is crucial; the monitoring process should address both environmental effects and technological performance;

- The formal environmental assessment should not be the only means of communication when a specific proposal is before the public; and

- The environment is a "public good." To be effective, environmental governance must be characterized by transparency, lack of bias, accessibility, competence and public accountability.

Nuclear Communities

The NWMO has determined from early research and discussions that the communities which currently store nuclear fuel waste have special experience, insights and perspectives which should be drawn upon to help inform the work of the NWMO. Additionally, within these communities there is a wide spectrum of perspectives and concerns that in many ways reflect the diversity of views across the country. Accordingly, the NWMO determined that an important focus for engagement is with and within these reactor site communities.

On October 7 - 8, 2003, a Community Dialogue Planning Workshop was convened to develop and design ways through which the NWMO could facilitate effective and responsive dialogue and communication at the community level. The NWMO wants to enable the communities to participate meaningfully in the NWMO work in a manner responsive to their concerns and interests. Twenty-one individuals participated, representatives of various community perspectives (including environment, labour, industry, business, citizen, health, local government, etc.).

The discussions addressed matters such as the principles of participation; features which make a process fair; and key factors that lead to success or failure in a community based process. Considerable discussion was held on the feasibility of the NWMO establishing community specific dialogue forums, which would undertake community liaison/co-ordination work to maximize the effectiveness of community-based dialogue.

Technical Aspects

The technical aspects of managing nuclear fuel waste were examined in a workshop conducted at McMaster University in Hamilton, Ontario in September 2003. Approximately 50 experts participated, drawn from business and industry, academia, government, and the not-for profit sector (See Appendix 1).

Participants provided advice on the key technical questions: storage, disposal and reprocessing of used nuclear fuel. Among the issues:

- Technological requirements that make nuclear waste different from other wastes;

- The extent to which each method can be considered a stand-alone method for managing used nuclear fuel;

- The extent to which the volume of waste to be managed is an important factor in assessing feasibility and appropriateness of the methods;

- The relative risks and benefits associated with transporting waste;

- Technological requirements to allow for:
  - flexibility in decision making;
  - extended monitoring;
  - retrievability;
  - larger or smaller volumes of waste;
  - different types of used nuclear fuel;

- The possibility of, and timeframe for, developing new technologies and/or breakthroughs; and

- The technological and scientific pros and cons of recycling the material; factors to consider include:
  - the differing technological requirements in instances where the technology is used for reuse/recycling, storage, disposal;
  - minimizing radioactive dose and/or toxicity;
  - the potential for diversion and non-proliferation.

Factual Background

Canadian and international experts were commissioned to provide the NWMO with up-to-date information on our current state of knowledge. To date, numerous papers have been commissioned addressing such topics as:

- potential management systems;

- the status of biospheric and geospheric research;

- lessons learned from other experiences in hazardous waste management;

- financing considerations; and

- various aspects of our legal and administrative frameworks.

A full listing of these papers is provided as Appendix 3, and the papers are posted on-line at www.nwmo.ca .

Important Lessons Learned

We have learned some key lessons about the issue of managing used nuclear fuel by looking at the question from a variety of perspectives, and by applying some broad concepts, such as "sustainable development," "ethics," and so on:

- In deciding on a management approach, it is important to consider the impact of decisions not only on ourselves, society and the environment right now, but also how those decisions will affect the well-being of future generations. There needs to be a sense of 'equity' or 'fairness' in how costs, benefits and risks are shared – not only among those now living, but across generations.

- Risk and uncertainty are important issues which need to be addressed in choosing a management approach. Although much is known, there is some risk and uncertainty associated with predicting: (1) how nuclear waste management approaches will perform over many thousands of years; and (2) the capabilities of future societies to take care of this material should it be required. Our early conversations suggest that, throughout the study, it is important to address risk and uncertainty clearly.

- Scientific and technical evidence and analysis, while essential to the task of assessing and addressing risk and uncertainty, cannot be the sole basis of decision-making. Equally important we need to consider the values of Canadians, impacted individuals and communities. Alternative social and ethical values need to be clearly identified, and assumptions examined, throughout the study.

- We must take into account both quantifiable and non-quantifiable (or qualitative) costs, benefits and risks.

- Social institutions, rules, regulations and systems which are in place are important considerations in assessing management approaches. While our collective capacities to act, to monitor, to regulate and to make adjustments are matters of uncertainty, there is also an opportunity to strengthen and enhance each management approach.

- There is value in 'flexibility' because it allows us to:

  - incorporate new knowledge as it becomes available;

  - adjust to the nature and magnitude of used nuclear fuel, if projections of these characteristics change; and

  - respond to societal or policy shifts beyond the scope of this study.

KEY QUESTIONS

The activities described earlier are all aimed at identifying the issues, concerns, challenges and uncertainties expressed by Canadians. An early sense of the key questions that will form the backbone of the analytical framework is now emerging. The answers to these questions will provide a basis for assessing management approaches.

These questions attempt to reflect Canadian values, while maintaining our commitment to recommending a management approach that is socially acceptable, technically sound, environmentally responsible and economically feasible.

The questions listed here are intended to spark discussion and generate feedback. For many, the "devil is in the detail" and what is found here will go through many iterations before the final form is settled.

For clarity, the questions have been grouped into five categories. Some questions will appear in several categories, as they reflect cross-cutting issues.

Key Questions

OVERARCHING ASPECTS

These questions apply to all aspects of the framework. Together, they ensure that insight is drawn not only from the perspective of specific disciplines, but also from a more holistic, overarching perspective.

TEMPLATE OF KEY QUESTIONS

Overarching Aspects
- Q.1 Institutions and Governance
- Q.2 Engagement and Participation in Decision making
- Q.3 Aboriginal Values
- Q.4 Ethical Considerations
- Q.5 Synthesis and Continuous Learning

Social Aspects
- Q.6 Human Health, Safety and Well-being
- Q.7 Security

Environmental Aspects
- Q.8 Environmental Integrity

Economic Aspects
- Q.9 Economic Viability

Technical Aspects
- Q.10 Technical Adequacy

Q.1

INSTITUTIONS AND GOVERNANCE

Does the management approach have a foundation of rules, incentives, programs and capacities that ensure all operational consequences will be addressed for many years to come?

To answer the question, each management approach would have to be considered in terms of whether or not:

- an efficient and effective mix of legislated rules, voluntary programs, market incentives and cultural norms is in place;
- national and international laws, regulations, and conventions are respected;
- regulations and standards are in place to adequately protect human and environmental health;
- a reasonable degree of confidence would be held by those affected, that adequate capacity and resources would be put in place to address consequences over the long term; and
- a reasonable degree of confidence would be held by those affected that commitments made would be fulfilled.

Key Questions

Q.2

ENGAGEMENT AND PARTICIPATION IN DECISION-MAKING

Does the management approach provide for deliberate and full public engagement through different phases of the implementation?

The effective participation of those affected is a constant theme, heard not only throughout all of the early NWMO activities, but also in many parallel initiatives. It is a fundamental tenet of practical application of sustainability.

To answer the question, each management approach would have to be considered in terms of whether or not:

- there are commitments to community engagement, designed and implemented that ensure all affected communities of interest (including vulnerable or disadvantaged groups) have the opportunity to participate in the decisions that influence their future, and are understood and agreed to by the communities of interest;
- there are "understood and agreed-to" mechanisms that address such issues as dispute resolution and systems of reporting and verification that would allow periodic testing of the effectiveness of engagement processes; and
- there is an opportunity to seek informed and voluntary consent of those affected by the project.

Q.3

ABORIGINAL VALUES

Have aboriginal perspectives and insights informed the direction, and influenced the development of the management approach?

To answer this question, consideration will need to be given to whether or not:

- spiritual and physical aspects of the land, people, wildlife and their habitat have been appropriately considered;
- the relationships between various aspects of the environment, including humans, have been appropriately considered;
- the aboriginal sense of responsibility and stewardship has been respected;
- the subsistence, health, trade and spiritual needs of people have been appropriately considered; and
- conditions have been appropriately identified and considered in advance of the project development proceeding.

Key Questions

Q.4

ETHICAL CONSIDERATIONS

Is the process for selecting, assessing and implementing the management approach one that is fair and equitable to our generation, and future generations?

To answer this question, consideration will have to be given to whether or not:

- ethical-impact analyses have been undertaken to address problems such as environmental justice and violations of rights to know, of due process, of equal protection, to life, to free informed consent, and to be compensated for harms/threats of harm;
- the management approach has been tested for its capacity to ensure a fair sharing of costs, benefits, risks and responsibilities both now and in the future; and
- the deliberative decision-making process undertaken by the NWMO has been tested, to ensure it has been carried out in an ethical fashion.

Q.5

SYNTHESIS AND CONTINUOUS LEARNING

When considered together, do the different components of the assessment suggest that the management approach will contribute to an overall improvement in human and ecosystem well-being over the long term? Is there provision for continuous learning?

Each management approach would be considered in terms of whether or not:

- the assessment provides a comprehensive, integrated, picture that brings together for review the many implications of a management approach;
- the management approach provides a strong foundation for continuous learning;
- there is a system proposed for periodic reassessment of all factors; and
- the principles of continuous learning and improvement embedded in the proposed management approach.

Other considerations include:

- How often opportunities for continuous improvement and learning will be reviewed; and
- If course correction is required, the actions needed to occur to make mid-course changes possible.

Key Questions

SOCIAL ASPECTS

These questions encompass concerns that focus on people and society. Uppermost in the minds of Canadians are issues of health, safety and security. This message has been a constantly-occurring theme, not only in the early work of the NWMO, but throughout the nuclear debate in Canada over the past 40 years.

Q.6

HUMAN HEALTH, SAFETY, AND WELL-BEING

Does the management approach ensure that people's health, safety and well-being are maintained (or improved) now and over the long term?

To answer the question, each management approach would be considered in terms of its capacity to ensure:

- that worker and population health, safety and security will be maintained (or even improved) over time;
- that social and cultural integrity in the region will be maintained (or even improved) over time; that traditional and cultural attributes will be maintained and nourished, consistent with the goals of the community;
- that local people will be confident that they can influence decisions that affect their own future;
- that the management approach address traditional and cultural attributes in the surrounding community and contribute to the long-term viability of traditional and non-market activities (which includes all of what we do that is not bought or sold in the market, including faith and cultural oriented activities, the wide range of volunteer activities, and housework) activities, consistent with the goals of the community;
- that effective organization and capacity are in place, not only within the management facility, but also in the community;
- that direct, indirect and induced effects would be considered and addressed;
- that all social/cultural costs, benefits and risks are considered and addressed;
- that the management approach has an acceptable overall level of risk to people and society;
- that a mechanism is included to identify, assess and publicly report the "equity" of the distribution of costs, benefits and risks, from the perspective of various interests;
- that a reasonable degree of certainty can be expected by all interests that the responsibilities and sureties for short and long-term human well-being are fully and fairly assigned and accepted; and
- that all forms of stress imposed on individuals (workers and residents), their families and the community as a whole, is assessed and actions are proposed to ensure that they lie within "acceptable" levels.

Key Questions

ENVIRONMENTAL ASPECTS

These questions relate to concerns and issues about environmental conditions and the stresses that human activity imposes on the environment.

Q.7

SECURITY

Does this method of dealing with used nuclear fuel adequately contribute to human security? Will the management approach result in reduced access to nuclear materials by terrorists or other unauthorized agents?

Among the key issues is the capacity of the management approach to maintain its intended integrity in the face of:

- extreme natural events (storm, meteorite, earthquake, dramatically changed temperature regime, glaciation, ozone depletion);
- accidents; and
- acts of terrorism and malice.

We would need to test contingency plans, to determine if they can adequately address security concerns.

Q.8

ENVIRONMENTAL INTEGRITY

Does the management approach ensure the long-term integrity of the environment?

This is another consistent theme, not only in NWMO activities, but across society as a whole. To answer the question, each management approach would have to be considered in terms such as whether:

- the management approach would lead to confidence that ecosystem function and resilience, and self-organizing capacity, is being maintained (or improved) over the long term;
- elements of the ecosystem that are affected by the management method are being maintained (or improved) in order to meet the needs of current and future generations;
- the full costs, benefits and risks to the ecoysystem are considered;
- the management approach carries an acceptable overall degree of risk, including risk to the environment;
- the responsibilities and sureties for long-term integrity of the ecosystem are fully and fairly assigned and accepted;
- the management approach leads, directly or indirectly, to maintaining (or strengthening) the integrity of biophysical systems, so they continue to support the well-being of people and other life forms; and

Key Questions

ECONOMIC ASPECTS

These questions relate to the economic viability of any management approach and the guarantee of adequate economic resources throughout the life of the project. This assessment is required under the legislation.

Q.8 (continued)

ENVIRONMENTAL INTEGRITY

- all forms of stress (physical, chemical, biological) on the environment have been considered, and appropriate mitigation proposed. Stressors might include:
  - stress imposed on the environment by the ongoing management approach (including infrastructure and support systems);
  - the cumulative effect of stress on all elements and processes of the ecosystem; and
  - stress imposed by potential failure of containment.

Q.9

ECONOMIC VIABILITY

Is the economic viability of the management approach assured and will the economy of the community (and future communities) be maintained or improved as a result?

To answer this question, each management approach should consider such factors as whether:

- cost estimates are complete; that they take into account alternative future scenarios of the magnitude of the waste stream; that they reflect the best available social and technical knowledge;
- adequate funds are set aside and available to finance the approach, offering secure and sustainable financial arrangements that will endure a long-term planning horizon;
- significant negative socio-economic impacts will be avoided or minimized;
- the financial health of the management approach and the community are assured over the long-term;
- appropriate consideration has been given to intergenerational transfer issues; and
- appropriate contingencies have been established and addressed, for example, transportation accidents, a major economic recession, an extreme natural event (such as a major earthquake).

Key Questions

TECHNICAL ASPECTS

These questions focus on the adequacy of the management approach from a technical perspective.

Q.10

TECHNICAL ADEQUACY

Is the technical adequacy of the management approach assured and are design, construction and implementation of the method(s) used in the management approach based on the best available technical and scientific insight? By method, we mean the technical method of storage or disposal of the used fuel.

To answer this question, each management approach should consider such factors as whether or not:

- peer review assures that the best available technical and scientific insights have been used;
- the experiences of other countries are being considered in the assessment of the relative merits of different methods of storage or disposal;
- all technical barriers and opportunities are adequately considered;
- effects on both natural and anthropogenic processes have been considered;
- cumulative economic, social and environmental implications of the technical method are considered over both the short and long term;
- the potential for catastrophic failure of containment systems, including those used for transportation, are considered;
- adequate contingency planning is included;
- long-term residual impacts are considered;
- the effects of global climate change are factored into the design;
- an appropriate degree of flexibility is allowed for in the technical design criteria;
- there is appropriate technical monitoring and reporting; and
- opportunity for adaptability or change is sustained.

APPLYING THE ANALYTICAL FRAMEWORK

From its inception, the NWMO has committed to "develop collaboratively with Canadians a management approach for the long-term care of Canada's used nuclear fuel that is socially acceptable, technically sound, environmentally responsible, and economically feasible." Each step of the study will be open for public review and input.

With the release of this Discussion Document, the NWMO will seek to engage interested Canadians in a dialogue on whether the questions listed in this document are in fact the right questions to ask, and answer, in this study. Are we asking the right questions? In response to the comments of Canadians over the next several months, we will then refine, modify and/or change this list of questions to reflect the direction of Canadians.

Once we are assured that we have the right starting point for the study with this list of questions, we will then move to identify the criteria to be used to begin to answer these questions. These criteria will be identified through dialogue. The NWMO will engage individuals with expert knowledge from a wide variety of perspectives, and other interested Canadians, to help assemble a range of criteria which could be used to explore each of the questions. The NWMO will summarize and present this list of criteria in our second discussion document. The NWMO will then seek to engage Canadians in a dialogue about the appropriateness of these criteria both in general, and as they have been applied to describe the management approaches in the months following release of the second Discussion Document.

Our third Document, the Draft Final Report will set out the recommendations, including plans for implementation. In formulating a final recommendation, the NWMO needs to understand and impute importance to individual criteria, and determine and implement acceptable trade-offs. The NWMO will need to explain to government, and Canadians, how the decisions made in both of these areas are responsive to the societal direction we have received. The need for this ultimate explanation and account will drive decisions on the extent to which a more or less formal weighting scheme will be identified and applied.

In addition, a panel of internationally-recognized experts will review the analytical framework as it evolves to ensure it:

- is robust;
- addresses technical, scientific and social acceptability assessment criteria; and
- incorporates the best available insight from international research in describing the management approach, in identifying and describing the implications and in the comparative assessment itself.

Underlying the analytical framework are a number of challenges which will need to be addressed throughout the study, concerning how best to:

- characterize and assess risk;
- address scientific, social, and ethical uncertainties;
- distribute benefits, costs, and risks;
- address disputes;
- appropriately include consideration of values, ethics and our own value judgments; and
- build trust and robustness into the system.

Chapter 4 / The Alternative Methods

4

BACKGROUND

The 2002 *Nuclear Fuel Waste Act* directs the NWMO to examine three methods for the long-term management of used nuclear fuel:

- deep geological disposal in the Canadian Shield;
- storage at nuclear reactor sites; and
- centralized storage (either above or below ground).

In addition to these three methods, many others have been advanced in the past, by governments, industry and researchers. It is within the NWMO's mandate to examine any, or all, of these approaches, and options that have not been proposed in the past, as may be appropriate.

For the purposes of this study, we have defined a "method" to be a technology, technique, technical process or procedure for handling used nuclear fuel. In the following discussion of methods, the terms disposal, storage, and treatment are used frequently; to ensure clarity, they are defined and described in the side bar "Key Terms".

A central task is to establish how extensively we consider any given technical method. We believe that at this early stage, we should review all the different methods that have been advanced over the years. However, there are many and clearly, not every one is equally important. Thus, in the next phase of our work, we need to decide which management methods should be emphasized as we conduct our comparative assessment. In doing this, we will be guided by the best advice available from within Canada and internationally.

Key Terms

DISPOSAL: A method of isolating used nuclear fuel from humanity and the environment; the method must be conclusive and without the intention of retrieval or reuse.
In principle, disposal can be achieved by placing the waste deep underground, at sea, in ice sheets, in space, or in deep boreholes. Internationally, the most commonly pursued disposal method is to place the used fuel deep in a geological repository which can involve horizontal emplacement in a mountain (as in the U.S.), or vertical emplacement deep underground in stable rock (as in Sweden and Finland). In addition to "engineered barriers" offered by the containers and other design considerations, geological disposal methods rely on depth (at least a few hundred metres below the surface) and the geology of the area to provide additional natural barriers to slow the movement of radionuclides which may eventually be released from the used nuclear fuel. Geological disposal methods are also seen to provide protection to humanity and the environment, should institutional controls fail. Disposal methods may require transporting used nuclear fuel to a centralized location, whether in the home country, to an international repository, or to an offshore location.

STORAGE: A method of maintaining used nuclear fuel in a manner that allows access, under controlled conditions, for retrieval or future activities.
Most storage methods rely on engineered barriers for radiation protection. The used nuclear fuel is placed in engineered facilities (which

can be concrete containers, silos or modules) at or below the surface (in vaults or caverns). Some countries, like Sweden, use underground wet fuel bays for storage. Storage methods can vary widely depending on the duration of time the used nuclear fuel is to be stored, the amount of used nuclear fuel to be stored, the number of storage locations, as well as the existing interim storage facility design (some may require repackaging). Storage methods require institutional controls; they may require repackaging of the fuel containers over time, and will require transportation if the storage facilities are not located at the reactor site where the waste is created.

TREATMENT: Processes applied to used nuclear fuel that change its characteristics. Currently these include processes that reduce the volume of the used nuclear fuel and separate the components for individual treatment (reprocessing, partitioning and conditioning). Some countries have programs in place to further examine and optimize these treatment processes. Also included in this category are processes to reduce the radiotoxicity of the used nuclear fuel (transmutation). A few countries are doing research in this area, but the process is still largely developmental. Treatment methods involve applying chemical and physical processes to the used nuclear fuel, recovering desirable components and separating and treating residual, radioactive and hazardous waste streams. Treatment methods may require that the used nuclear fuel be transported to the treatment facility, and recovered components and residual waste streams may need to be transported back.

We have characterized specific methods as follows:

- those requiring review under the NFWA;
- those receiving significant international attention; and
- those that have been examined previously and, while they may still be advocated by individuals or organizations, are not being implemented nor are the focus of major research effort.[28]

We want to know if Canadians agree with this general perspective.

METHODS REQUIRING REVIEW UNDER THE NUCLEAR FUEL WASTE ACT

The *Nuclear Fuel Waste Act* obligates the NWMO to examine, in detail, three management methods. Countries other than Canada are also actively examining or implementing these methods.

Deep Geological Disposal

Disposal is a method of isolating used nuclear fuel from humanity and the environment. It is conclusive and without the intention of retrieval or reuse.

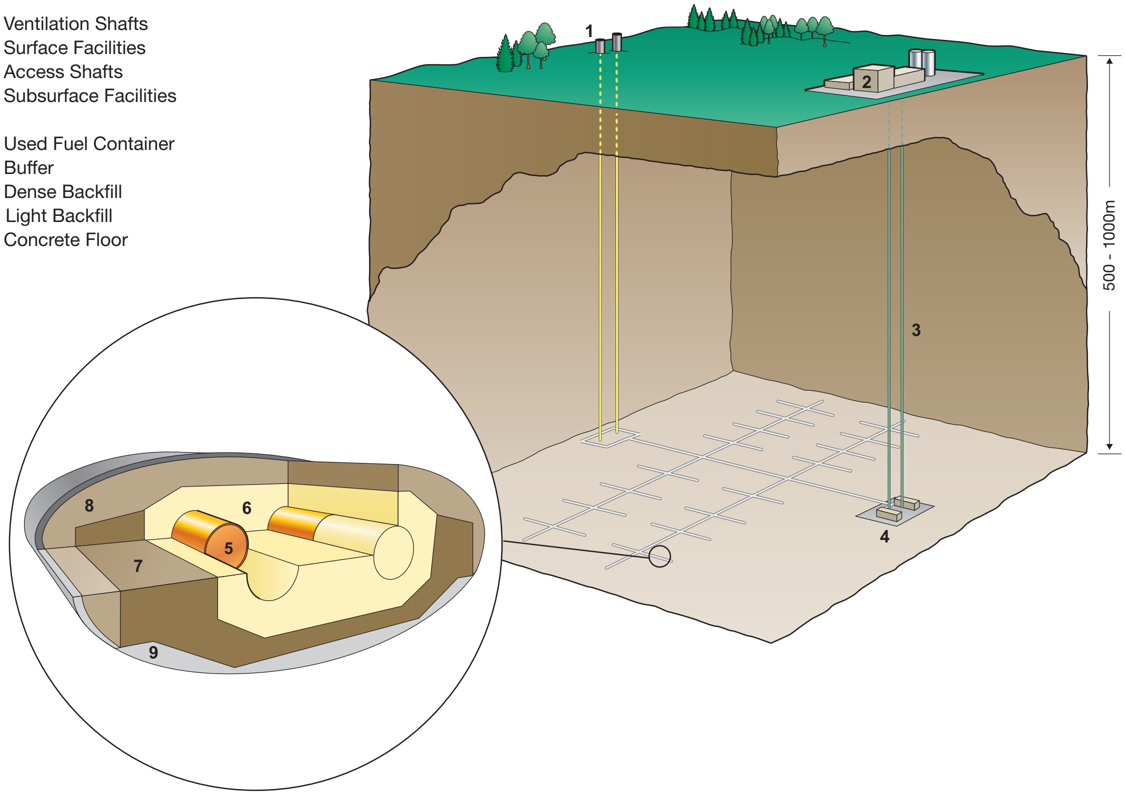
Deep geological disposal involves burying the used nuclear fuel deep underground. This method is currently favored by many countries and by most international agencies[29]. It would require transporting used fuel from interim storage facilities to a disposal facility (wherever it is located).

The main challenge in effective disposal is to limit the potential for migration of radioactive and toxic contaminants away from the used nuclear fuel. The most worrisome migration process is through the groundwater flow system. Even if contaminants moved one metre per year – that still means the contaminant stream could be five kilometres long in 5,000 years, if ever the contaminants breached their containment barriers.

FIGURE 4.1
Current concept of a Deep Geological Repository.

1. Ventilation Shafts
2. Surface Facilities
3. Access Shafts
4. Subsurface Facilities

5. Used Fuel Container
6. Buffer
7. Dense Backfill
8. Light Backfill
9. Concrete Floor



In the AECL disposal concept (the specific concept referred to in the Act), multiple barriers are proposed for limiting such movement. Barriers include:

- the fuel pellet itself, which is made of ceramic and retains almost all of the fission products;
- the Zircaloy holding tube that seals in the pellets;
- the waste container of materials selected to inhibit corrosion, cracking and perforation;
- multiple buffer zones surrounding the waste container; and
- a host geological medium that naturally limits long-term contaminant movement.

If contaminants should escape from the engineered containment, their movement would depend on the nature of the contaminants themselves, the host rock and the groundwater flow system. Several rock types naturally impede these movements, including granite, rock salt, sedimentary clay and volcanic tuff and, depending on local hydrogeological conditions, can be advantageous as host rock.

In Canada, the stable plutonic granites of the Canadian Shield have been the focus of investigation. In Germany, the feasibility of burial in rock salt formations has been assessed. Switzerland has examined clays, and the U.S. Federal Government has made a commitment to Yucca Mountain, which is composed of unsaturated tuff rock formed by the accumulation of glassy fragments from a volcanic eruption[30].

Industry has continued work on key issues around a deep geological repository in Canada. One design proposes that 324 fuel bundles would be contained in a steel inner vessel which is surrounded by a copper outer shell. The fuel container would be encapsulated in bentonite self-sealing clay which, in turn, would be packed in a buffer material, a dense backfill, and a light backfill. The container would be buried 500 – 1000 meters below the surface of the Canadian Shield. Figure 4.2 illustrates the extent of the Canadian Shield.

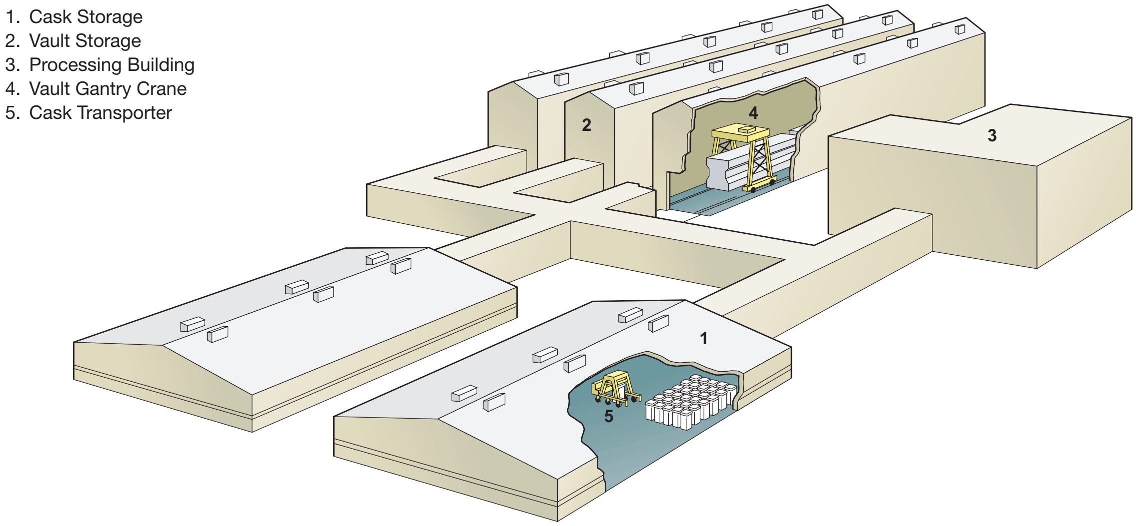


FIGURE 4.3
Current concept of above-ground centralized extended storage: casks and vaults in storage buildings

FIGURE 4.2
Distribution of the granitic rocks of the Canadian Shield.

Models have predicted that the depth of the facility, the rock and the nature of the groundwater flow system would, in combination, greatly impede the movement of radioactive and toxic contaminants. The location could withstand significant geological change and extreme events (storms, earthquakes, meteor impact, glaciation and changes in temperature).

Originally, the AECL concept of deep geological disposal included backfilling and sealing the repositories soon after waste emplacement. Today, however, some countries are considering a "staged" approach in which final closure would be postponed for many years. In the meantime, this would mean fuel could be retrieved, should that be desirable.

This staged approach may also allow further research to be undertaken and technical change to take its course. Also, monitoring systems would allow us to see how effectively the system is functioning.

The AECL approach and the staged approach are sometimes referred to as the "early seal" and "late seal" options. A "no-seal" option is also possible; this would really be a form of extended centralized storage and is described next.

Centralized Storage

Storage is a method of maintaining used nuclear fuel in a manner that allows, under controlled conditions, access for retrieval or other future activities. Long-term storage at a central site requires transporting the fuel from the reactor sites. Storage facilities can be located either above or below ground.

Facilities above ground can be designed with varying degrees of longevity in mind. 'Conventional' storage buildings could be designed that may need to be replaced every century or so, depending upon the durability of the construction materials that are used. Alternatively, more permanent engineered structures could be designed to remain sealed for up to several thousand years.

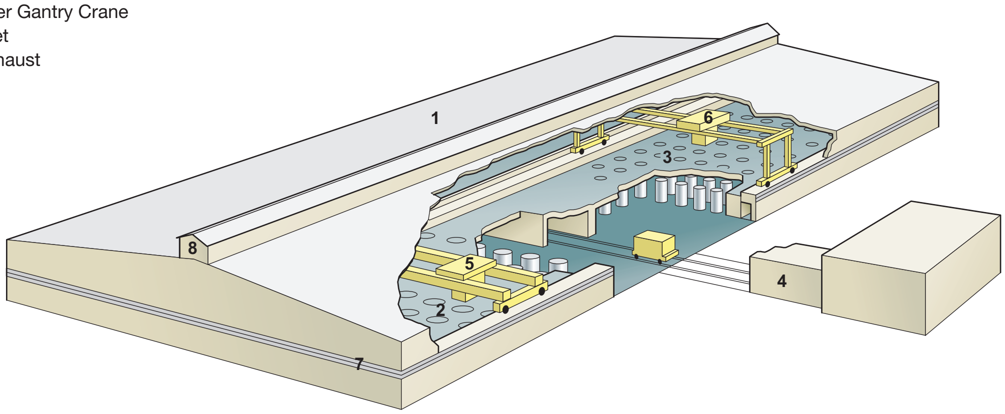
Underground storage is either by shallow burial or in caverns or tunnels some tens of metres beneath the surface. The goal is to enhance the degree of security (compared to above-ground methods) while retaining the ease of fuel retrieval[31]. The facilities' integrity would depend on ongoing maintenance, and future generations would inherit oversight-related responsibilities.

Here in Canada, industry has completed a preliminary review of centralized extended storage. Their above-ground alternatives include casks and vaults in storage buildings; and surface modular vaults. Below-ground alternatives include casks and vaults in buried storage containers; and casks and vaults in rock caverns. These alternatives are shown for above ground centralized extended storage in Figures 4.3 and 4.4.

The alternatives for below-ground centralized extended storage: casks and vaults in buried storage containers; and casks and vaults in rock caverns are shown in Figures 4.5 and 4.6.

FIGURE 4.4
Current concept of above-ground centralized extended storage: surface modular vaults

1. Storage Building
2. Module Canister Storage Vault
3. Basket Storage Vault
4. Transfer Route from Processing Building
5. Canister Handling Machine
6. Basket Transfer Gantry Crane
7. Ventilation Inlet
8. Ventilation Exhaust



Reactor-Site Extended Storage

Both above and below-ground storage alternatives are in use today. Additional possibilities could be designed by simply scaling down the designs and costs of the larger versions of centralized facilities. Each site has its own distinguishing characteristics, and many conditions must be factored into the design, construction, operation and maintenance processes. The breadth of variation is shown in Table 4.1, which describes the alternatives that have received at least some degree of review at various sites in Canada.

Above-ground storage facilities have been operational for a number of decades. However, underground interim storage facilities for used nuclear fuel have not been widely developed – most storage facilities are above ground. The best-known example of an operating underground interim storage facility is the CLAB facility in Sweden, where used fuel is stored in pools some 30 metres below the surface; this is in fact a centralized storage facility, not a reactor site storage facility. France is currently examining 'very long-term interim storage' methods, involving either near-surface pools like CLAB, or deeper facilities set in small hills.

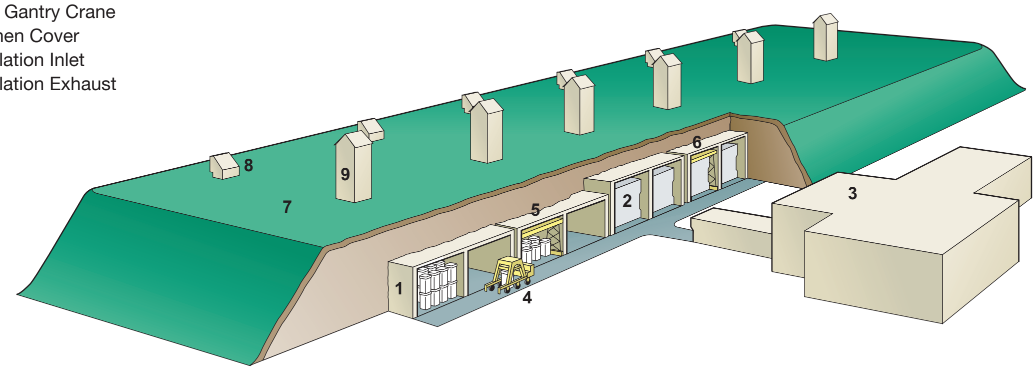
One advantage of storing used fuel at the reactor site is that it eliminates the need to transport the fuel to another (centralized) location. Further, because there are multiple facilities, no single facility is particularly large.

TABLE 4.1
Design methods considered for reactor site extended storage.

OWNER/SITE	DESIGN METHODS CONSIDERED
OPG and Bruce Power (Bruce A and B, Pickering A and B, Darlington)	• casks in storage buildings • casks in buried concrete chambers • surface modular vault
Hydro Québec (Gentilly 2)	• outside vaults • vaults in buried concrete chambers • surface modular vault
New Brunswick Power (Point Lepreau)	• outside silos • vaults in buried concrete chambers • surface modular vault
Atomic Energy of Canada Ltd., Chalk River	• outside silos • silos in buildings • silos in buried concrete chambers
Atomic Energy of Canada Ltd., Douglas Point	• fuel stored with OPG at Bruce
Atomic Energy of Canada Ltd., Gentilly 1	• fuel stored with Hydro Quebec at Gentilly 2
Atomic Energy of Canada Ltd., Whiteshell	• outside silos • silos in buildings • silos in buried concrete chambers

FIGURE 4.5
Current concept of below-ground centralized extended storage: casks and vaults in buried storage containers

1. Cask Storage
2. Vault Storage
3. Processing Building
4. Cask Transporter
5. Cask Gantry Crane
6. Vault Gantry Crane
7. Earthen Cover
8. Ventilation Inlet
9. Ventilation Exhaust



METHODS RECEIVING INTERNATIONAL ATTENTION

This discussion looks at additional methods that are being considered in some national programs around the world, and at methods that are likely to receive some attention in the future.

Reprocessing, Partitioning and Transmutation[32]

"Processing" refers to the preparation of fresh fuel before it goes into the reactor. "Reprocessing" is a general term for applying chemical processes to used nuclear fuel for the purpose of recovery and recycling of fissionable isotopes.

No country currently employs reprocessing for the sole purpose of managing nuclear waste. The primary purpose is to recover and reuse materials extracted from the used fuel. The long-term management of the residual wastes must still be addressed.

Reprocessing technology first was developed and exploited in the nuclear weapons programs of such countries as the United States, the United Kingdom, Russia, then later in the military programs of a number of some other countries, including France, China and India. The aim was to extract weapons-grade plutonium from used nuclear fuel. (The other main weapons material, uranium-235, is produced in uranium-enrichment plants specifically for military purposes). This military-related investment in infrastructure has significantly influenced the choice of fuel cycle-related infrastructure in countries that have later begun civilian nuclear power programs.

Recently, because of nuclear disarmament initiatives in the United States and the former USSR, the need for uranium recycling – and for the recovery of plutonium for fast reactors – has declined, as has interest in weapons-related reprocessing. At the same time, interest has increased in the possible use of reprocessing to mitigate some of the problems associated with the disposition of used nuclear fuel.

Reprocessing takes place after the used nuclear fuel has cooled for a few years. The fuel is moved to a reprocessing facility where it is stored in large lead and steel casks. There, it is dissolved in nitric acid and the volatile radioactive gases are carefully contained. Separation and segregation processes isolate products into different streams, such as useable uranium and plutonium; highly radioactive liquid waste; and less radioactive solids, liquids, and gases. These processes are referred to as "partitioning."

Reprocessing and partitioning rearrange and recycle components. A further process might be developed to actually transform some radioactive components into non-radioactive elements, using nuclear reactions initiated by neutrons or protons. This process changes one element to another, and is called "transmutation."

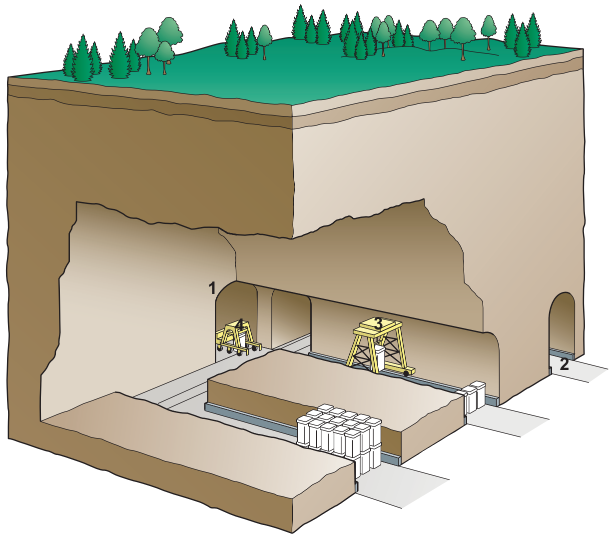
Transmutation is the subject of research programs in many countries, including Japan, France, the United States, Russia, the Republic of Korea and Italy, as well as the European Community[33]. The process is of interest because successful transmutation could significantly reduce the time horizon of risk associated with used nuclear fuel, unwanted nuclear weapons and surplus plutonium.

Storage or Disposal at an International Repository

In the early 1990s, the international organization Pangea conceived of an international repository project. The project was based on the conviction that the long-term containment of nuclear waste materials would be easier to demonstrate and achieve if a simple, stable geological environment

FIGURE 4.6
Current concept of below-ground centralized extended storage: casks and vaults in rock caverns

1. Access Ramp
2. Cask Storage Cavern
3. Cask Gantry Crane
4. Cask Transporter



were chosen using global considerations, rather than being hindered by artificial national boundaries[34]. Natural geological barriers would, it was claimed, provide the main measure of safety, and would avoid the need for complex engineered solutions. Using geological and climatic data, broad regions were identified as potentially able to provide optimal conditions for an underground repository.

Pangea sought to identify and develop a high-isolation site for a repository capable of accepting used fuel and high-level waste from any country. A potentially suitable site was identified in Australia, but there was considerable political opposition and the project was abandoned. Pangea itself ceased activities in 2002 and was replaced by the Association for Regional and International Underground Storage (ARIUS). Membership is open to organizations and individuals who support these aims. ARIUS is currently lobbying national and international bodies with a view to developing pilot facilities. This is the only body actively pursuing international disposal, although a proposed Directive from the European Commission recommends that such methods should be explored[35].

In April 1999 an American company, 'Non-Proliferation Trust Inc.' (NPT) was established to pursue developing an international storage facility at Zheleznogorsk in Russia. The facility, with a design life of 40 years, would be developed in an existing cavern in a hillside, employing dry storage casks. A memorandum of understanding between NPT and the Russian nuclear ministry was signed in 2000.

Any assessment of international storage or disposal would necessarily include all the costs, benefits and risks of the site and related infrastructure (including transportation), linked to all affected societies and cultures. Transborder movement of used fuel would not be in violation of any international treaty, but in some cases might contravene the self-sufficiency principle that most countries with substantial nuclear programs apply to their radioactive waste management. This principle suggests that any state generating electricity using nuclear power must assume responsibility for the long-term management of used fuel within its own boundaries[36].

In theory, the design could be either above or below ground. The facility could either be based in another country and accept Canadian waste, or be based in Canada to accommodate its own and other countries' waste. Should this repository method be considered, a complex issue would be choosing a suitable site.

Emplacement in Deep Boreholes

Some countries, which must dispose of only small quantities of high-level waste, are looking at a method called "emplacement in deep boreholes." In this method, solid packaged waste would be placed in deep boreholes drilled to depths of several kilometres, with diameters of typically less than one metre. The waste containers would be stacked in each borehole and would be separated from each other by a layer of bentonite or cement. The borehole would not be completely filled with waste: the top two kilometres would be sealed with materials such as bentonite, asphalt or concrete.

Sweden, Finland and Russia, among others, have examined the deep borehole method as a possible alternative to a deep repository. Boreholes could be drilled both offshore and onshore in many types of rock, which broadens the number of possible disposal sites. Although proponents argue that related long-term risks to people and the environment would be very low, there are significant technical questions requiring further research.

METHODS OF LIMITED INTEREST

Eight methods are included in this category. They have been studied over the past 40 years, but none are being implemented, nor are they the focus of major research effort. Some are contrary to international conventions. Brief summaries are provided here to share information on the broad range of options that have been raised historically.

Direct Injection

This method involves injecting liquid radioactive waste directly into a layer of rock deep underground. The United States has used this method to dispose of liquid hazardous and low-level waste. The former Soviet Union has also used this method, to dispose of liquid high-level waste – at locations usually close to the waste generating sites.

Direct injection requires detailed knowledge of subsurface geological conditions. It does not incorporate any man-made barriers. There would be no control of the injected material after disposal. Retrieval would be impossible. There are many technical unknowns that would require extensive research to be confident of the suitability of this method for a specified site.

Although direct injection does not contravene international conventions, it would not be consistent with the spirit of international guidance on the long-term management of radioactive wastes.

Current published assessments do not suggest any substantive advantage and no country is pursuing direct injection as a means of dealing with an entire national inventory of used nuclear fuel.

Rock Melting

In this method, liquid or solid waste is placed in an excavated cavity or a deep borehole. Heat generated by the waste would increase, melting the surrounding rock and dissolving the radionuclides in a growing sphere of molten material. As the rock cools, it would solidify and incorporate the radionuclides in the rock matrix, dispersing the waste throughout a larger volume of rock.

In one variation of this method, heat-generating waste is placed in containers. When the rock melts around the containers, the waste is sealed in place.

Research was carried out on this method in the late 1970s and early 1980s, when it progressed to the stage of engineering design. The design involved a shaft or borehole which led to an excavated cavity at a depth of two to five kilometres. It was postulated (but not demonstrated) that the waste would be immobilized in a volume of rock one thousand times larger than the original volume of waste.

Another early proposal was to use weighted containers of heat-generating waste that would continue to melt the underlying rock, allowing them to move downwards to greater depths as the molten rock solidified above them. There was renewed interest in this method in the 1990s in Russia, particularly to dispose of limited volumes of specialized waste, such as plutonium.

Russian scientists have also proposed that high-level waste, particularly excess plutonium, be placed in a deep shaft and immobilized by a nuclear explosion which would melt the surrounding rock.

There have been no practical demonstrations that rock melting is feasible or economically viable.

Sub-seabed Disposal

In this method, radioactive waste containers are buried in a suitable geological setting beneath the deep ocean floor. Sub-seabed disposal was investigated extensively in the 1980s, primarily under the auspices of the Seabed Working Group set up by the Nuclear Energy Agency (NEA) of the Organization for Economic Co-operation and Development (OECD). Canada participated in this group, along with the United States, the United Kingdom, Japan and several European countries.

The sub-seabed disposal concept involves using missile-shaped canisters called "penetrators" to hold solid waste. The penetrators are dropped from ships, and bury themselves to a depth of a few metres or more in the sediments on the ocean floor. The disposal sites would be ones where the sediments have a high capacity to absorb radionuclides, and where the water is a few kilometres deep.

The idea behind the concept is that the waste form, inner canister, penetrator and sediments would provide sufficient protection to prevent the release of radionuclides into the ocean for thousands of years. When release finally does take place, it would occur very slowly and there would be substantial dilution.

An alternative concept would draw on deep sea drilling technology to stack waste packages in holes drilled to a depth of 800 metres, with the uppermost container about 300 metres below the seabed.

Research on sub-seabed disposal ceased in the early 1990s when it became clear that there would always be intense political opposition. International conventions may prohibit ocean access to a sub-seabed repository.

Another alternative concept is to access a sub-seabed location via on-land shafts and drifts. This is being studied in Sweden, where a deep geological repository would be located deep beneath the ocean floor. In this instance, the ocean itself is the last line of defense: in theory, if contaminants escaped and moved to the ocean environment, their volume would be small, and the buffering and diluting capacity of the ocean would mitigate any consequences.

Disposal at Sea

This method consists of placing packaged waste on the bed of the deep ocean. The packaging would consist of canisters designed to last for a thousand years or more. The waste would be in a solid form that would release radionuclides into the ocean very slowly when the canisters fail.

The site would be one where the water is a few kilometres deep, so that the waste would not be affected by human activity; there would be substantial dilution of radionuclides before they reach the surface.

Sea disposal was investigated by the NEA's Seabed Working Group, but not in the same detail as the sub-seabed disposal method. Sea disposal would be an extension of the 'sea dumping' method that was used until the early 1980s to dispose of solid low-level radioactive waste. It is now prohibited under international conventions.

Disposal in Ice Sheets

In this method, containers of heat-generating waste would be placed in very thick, stable ice sheets, such as those found in Greenland and Antarctica. Three possibilities have been suggested.

In the "meltdown" concept, containers would melt the surrounding ice and be drawn deep into the ice sheet, where the ice would refreeze above the wastes, creating a thick barrier.

In the "anchored emplacement" concept, containers would be attached to surface anchors that would limit the containers' penetration into the ice by melting at around 200-500 metres. This would allow for possible retrieval for several hundred years (before surface ice covers the anchors).

In the "surface storage" concept, containers would be placed in a storage facility constructed on piers above the ice surface. As the piers sank, the facility would be jacked up to remain above the ice for perhaps a few hundred years. Then the entire facility would be allowed to sink into the ice sheet and be covered over.

There has been very little work on disposal in ice sheets because there has never been enough confidence about predicting the fate of the waste; also, it is possible radionuclides could be released into the ocean. Further, disposal of radioactive waste in Antarctica is prohibited by international treaty. Denmark has indicated that it would not allow such disposal in Greenland.

Disposal in Subduction Zones

This method was initially proposed in the 1980s. In theory, it involves placing waste in a subducting (or descending) plate of the earth's crust. Subduction zones are always offshore, so this concept can be considered a variant of emplacement in the sea or beneath the seabed. The waste could be emplaced close to an active subduction zone by means of tunneling, deep sub-seabed boreholes, or free-fall penetrators.

Little attention has been paid to this method because of the inability to predict the fate of waste. It has been suggested that waste might return to the surface via volcanic eruptions. This method has also been seen as a form of sea disposal (and so would be prohibited by international conventions).

Disposal in Space

This method would permanently remove radioactive waste from earth by ejecting it into outer space. Alternative destinations that have been considered include the sun, orbit around the sun, and ejection beyond the solar system. This method has been suggested for disposing of small amounts of the most toxic waste. This method has never been part of any major research and development program. Opposition to disposal in space has been reinforced by the Challenger and Columbia accidents.

Dilution & Dispersion

The method would involve dissolving the fuel in acid, neutralizing the solution and discharging it slowly down a pipeline into the sea. The discharge site and rate would be such that radiation doses to people never exceed internationally-accepted limits.

Another possibility would be to transport the fuel solution by tanker to the open ocean and release it there.

"Dilution & Dispersion" differs from all other storage and disposal methods in that there is no containment of the waste or isolation from the environment. It has never been proposed or considered seriously for used nuclear fuel disposal because sea disposal is prohibited by international conventions.

FOCUSING OUR EFFORT

In moving forward, the NWMO is committed to ensuring that all of the technical methods specified under the *Nuclear Fuel Waste Act* are included in its study, and that at least one management approach for each method is assessed and given full consideration.

Although the Act specifically requires the NWMO to consider only one disposal method (deep geological disposal in the Canadian Shield) and two storage methods (centralized storage and reactor site storage), the NWMO may also consider combinations of methods. We are also prepared to consider other methods which are demonstrated to be reasonable alternatives.

We look forward to hearing any comments that you might have regarding the technical methods that you believe the NWMO should focus on in this study.

Chapter 5 / The Next Steps

The NWMO is committed to sharing its thinking as it evolves throughout the study. The study will proceed in stages with periodic reporting points. This will allow everyone to think through issues over time and contribute their reflections to shape the study results.

This document is the first of three that will be used to generate public dialogue. Table 5.1 summarizes the milestone documents, their purpose and the target release dates. After each report is published, we will actively seek public comment, critique and dialogue.

TABLE 5.1
Milestone documents

MILESTONE DOCUMENT	TARGET RELEASE DATE	PURPOSES
Discussion Document 1 **Asking the Right Questions?**	Late fall 2003	• to describe the NWMO's legislative mandate and our proposed approach to the study • to share, for discussion, some of the broad issues and concerns that have arisen in our early conversations with Canadians • to outline our initial thinking about building an "analytical framework" for assessing different approaches • to provide, as background for our engagement with Canadians, some important information on technical methods for managing used nuclear fuel.
Discussion Document 2 **Understanding the Choices**	Mid 2004	• to articulate a preliminary description of the alternative technical methods and the analytical framework, as modified through dialogue with Canadians • to provide a preliminary assessment of the alternative technical methods
Discussion Document 3 **Choosing a Way Forward (Draft)**	Early 2005	• to provide a refined comparative assessment of management approaches based on the results of the engagement activities • to propose implementation strategies • to articulate a draft set of recommendations for public review
Final Study **Choosing a Way Forward**	By Nov 15, 2005	• to provide a final comparative assessment of management approaches and implementation plans • to present the NWMO's final recommendations • to summarize public commentary on the alternative management approaches, including implementation strategy • to transmit the comments of the Advisory Council about the NWMO study and the proposed approaches

Please contact us at:

Nuclear Waste Management Organization
49 Jackes Avenue, First Floor
Toronto, Ontario M4T 1E2 Canada
Telephone: 416-934-9814 or 1-866-249-6966

Make an electronic submission at:
www.nwmo.ca

After publishing this Discussion Document, the NWMO will nurture a broad-based program of citizen and stakeholder engagement – to review and have a dialogue about the key perspectives and issues arising from this Discussion Document. As part of this process, at a minimum:

- the NWMO and the Canadian Policy Research Networks will hold a National Citizens' Dialogue between January and March 2004;
- the NWMO will sponsor roundtables and specialized workshops across Canada, including reactor site communities, and building upon the suggestions and advice given in our early activities of 2003;
- aboriginal consultations, designed by aboriginal organizations, will be held;
- our website - www.nwmo.ca – will feature a web-based dialogue, which will run during February and March; we will conduct ongoing on-line deliberative surveys to solicit feedback and input and we will receive electronic submissions from Canadians.

Through these formal and informal means, we want to pursue some key questions:

Have we described the problem correctly? Is our description of the history of this issue, the challenge facing Canada today and the characteristics of Canada's nuclear fuel inventory clear and understandable? Is there anything that should be added?

Have we identified appropriate ways to deal with the problem? Given limited time and resources, on which technical methods should we focus? Do you concur with our preliminary depiction of these methods? Do the methods we propose to study constitute a fair basis for developing an approach for Canada?

Are we asking the right questions? As we assess different methods, are we on the right track, in terms of capturing the key issues? Do you agree with the parameters and key questions suggested in Chapter 3? Are there specific issues that you would like considered as we assess different technical methods? What are some key considerations as we develop an implementation plan and overall management approach?

Is our proposed decision-making process understandable and appropriate? Have we captured the key elements? Are there other considerations that should be included?

We will use this input to further develop and refine the management approaches and prepare a preliminary comparative analysis of the options. This preliminary comparative analysis of the approaches will be shared in our next discussion document, planned for 2004.

The website will be the main repository of all information. We hope that you will check it regularly or contact us at the address above.

Your views deserve to be heard. We invite your active participation.

Figures and Tables

FIGURES

TABLES

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Appendices

APPENDIX 1 / ACKNOWLEDGEMENTS

Conversations about Expectations

The NWMO initiated face-to-face conversations with more than 250 individuals and representatives of organizations at local, provincial, national and international levels. These people included representatives of aboriginal organizations, nuclear power plant workers, youth, residents of nuclear power plant communities, environmental groups, industry experts, faith communities, business, government agencies and parliamentarians.

Public opinion research was also conducted – first through 14 focus groups in seven centres across Canada in 2002, then in a nationwide telephone survey of more than 1,900 randomly-selected Canadians in 2003.

The NWMO has also had conversations with the nuclear energy corporations who, as the owners of used nuclear fuel, have important expertise to share based on their knowledge acquired in managing the used fuel to date. This dialogue will continue to give the NWMO technical information (such as used nuclear fuel quantities and current interim waste management processes) and to learn of any recently-completed research.

In addition to these preliminary conversations, the NWMO has benefited from the insights and perspectives of a broad range of contributors as listed below. This preliminary contact has been of considerable importance in shaping our study plan and in educating us about the issues that matter to them. For their willingness to work with us, we are very grateful. We recognize that their participation in no way implies agreement with the NWMO, in terms of the nature of the process, the way ideas are expressed, or the substance of any future recommendations.

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APPENDIX 2 / A PROFILE OF THE NUCLEAR WASTE MANAGEMENT ORGANIZATION

NWMO MANDATE

The Nuclear Waste Management Organization (NWMO) was created under the provisions of the federal *Nuclear Fuel Waste Act* that came into force November 15, 2002.

The Act outlines the scope of the NWMO mandate, including the nature of the work required to study the alternatives, and to propose approaches for managing used nuclear fuel.

The Act required nuclear energy corporations that produce used nuclear fuel to establish a waste management organization to provide recommendations to the Government of Canada on the long-term management of used nuclear fuel.

The NWMO's focus will be on the long-term management of Canada's used nuclear fuel that results both from research nuclear fission reactors and from commercial reactors where used nuclear fuel emerges as a by-product of electricity-generation in nuclear power plants.

Consistent with the legislation, Canada's nuclear energy corporations – Ontario Power Generation, New Brunswick Power and Hydro-Québec – established the NWMO in 2002.

Following the requirements of the Act, the NWMO will develop collaboratively, with Canadians, a management approach for the long-term care of Canada's used nuclear fuel. The NWMO seeks to propose an approach that is socially acceptable, technically sound, environmentally responsible and economically feasible.

The *Nuclear Waste Fuel Act* also required that:

- the NWMO establish an Advisory Council whose comments on the NWMO's study and reports will be made public; and
- within three years of the legislation coming into force, the NWMO submit to the Minister of Natural Resources proposed approaches for the management of used nuclear fuel, along with comments of the Advisory Council, and a recommended approach.

The legislation authorizes the Government of Canada (the Governor in Council) to decide on the approach. The Government's choice will then be implemented by the NWMO, subject to all of the necessary regulatory approvals.

The *Nuclear Fuel Waste Act* is the most recent milestone in a 25- year program to identify and implement a long-term management approach for used nuclear fuel in Canada. The legislation represents, in part, the Government of Canada's response to the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel, which was chaired by Mr. Blair Seaborn and which reported in March, 1998.

For more detailed information please go to **www.nwmo.ca.**

NWMO BOARD OF DIRECTORS

The *Nuclear Fuel Waste Act* required the nuclear energy corporations to establish the NWMO. The composition of the NWMO Board of Directors is consistent with the *Nuclear Fuel Waste Act*, reflecting the Government of Canada's "polluter pay" principle.

The NWMO Board of Directors is currently composed of representatives of the major owners of Canada's used nuclear fuel.

The Board includes representatives from Canada's three main producers of used nuclear fuel: Ontario Power Generation, Hydro-Québec and New Brunswick Power. Members are: Richard Dicerni (Chair), Ken Nash (Vice-Chair), Laurie Comeau, Fred Long, Adèle Malo and René Pageau.

NWMO ADVISORY COUNCIL

The *Nuclear Fuel Waste Act* required the NWMO to establish an Advisory Council.

The NWMO established an arms-length, independent Advisory Council in 2002. It is a broad-based Council composed of individuals knowledgeable in nuclear waste management issues and experienced in working with citizens and communities on a range of difficult public policy issues. The Act mandates the Advisory Council to examine and provide to the NWMO its independent written comments on the study and the proposed approaches. Advisory Council comments provided to the NWMO will be included in the NWMO's study that is submitted to Government, and also made public.

In addition to commenting on the management approaches and the NWMO study, the Advisory Council will make important contributions to the NWMO through its ongoing advice and guidance to the NWMO Board of Directors and the President. For example, the Advisory Council will:

- Seek to ensure that the views of the public and communities of interest are considered and are reflected in a thoughtful, balanced way in the proposed approaches and reports of the NWMO;
- Assist the NWMO in ensuring that its processes are of good quality and are open, transparent, thorough and sound; and
- Regularly comment on the manner in which the NWMO discharges its responsibilities.

Council members are appointed for four-year terms. There are presently nine members of the Advisory Council:

The Honourable David Crombie
The Hon. David Crombie is President and CEO of the Canadian Urban Institute. A past mayor of the City of Toronto and a Privy Councillor, Mr. Crombie was the first Chancellor of Ryerson Polytechnic University. He is the recipient of honorary doctorates of law from the Universities of Toronto and Waterloo.

David R. Cameron
David R. Cameron is a Professor of Political Science and Acting Vice-Dean of Undergraduate Education and Teaching at the University of Toronto. He has held a number of senior government positions in both the federal and Ontario public service. He continues to advise on a wide range of governmental issues.

Helen C. Cooper
Helen C. Cooper has more than 25 years experience in community development, municipal governance, organizational planning and teaching. She is a former mayor of Kingston, Ontario. Ms. Cooper has contributed to a wide range of social and health initiatives at the municipal, provincial and federal levels.

Gordon Cressy
Gordon Cressy is the President of the Canadian Tire Foundation for Families. A past President of the United Way of Greater Toronto, he has held Vice-President positions at both the University of Toronto and Ryerson Polytechnic University. Mr. Cressy has a lengthy record of community involvement.

Fredrick Franklin Gilbert
Fredrick Franklin Gilbert is the President of Lakehead University in Thunder Bay, Ontario. He has had an extensive teaching and administrative career in the United States and Canada and has held several environmental and wildlife management public service positions.

Eva Ligeti
Eva Ligeti is presently the Executive Director of the Clean Air Partnership in Toronto. Ms. Ligeti served as Ontario's first Environmental Commissioner from May 1994 until 1999. She previously held the position of Principal, Sheppard Campus, Seneca College of Applied Arts and Technology. She has practiced law and served as legal counsel at the Canadian Environmental Law Association.

Derek Lister
Derek Lister is the Chairman of the Chemical Engineering Department at the University of New Brunswick in Fredericton. His main research interests are in the areas of chemistry and corrosion associated with nuclear systems.

Donald Obonsawin
Donald Obonsawin is President & CEO of Jonview Canada Inc. He has been Deputy Minister of seven Ontario government ministries over a 15 year period. He has also held senior positions with several federal ministries including Indian Affairs and Northern Development and Health and Welfare Canada.

Daniel Rozon
Daniel Rozon is Head of the Engineering Physics Department at École Polytechnique de Montréal. A member of the Canadian Nuclear Society, he is a recognized expert on nuclear affairs and is often called upon to discuss and advise on current issues in the sector.

APPENDIX 3 / LIST OF BACKGROUND PAPERS AND REPORTS

The NWMO has commissioned a series of papers and reports which present concepts and contextual information about the state of our knowledge on important topics related to the management of radioactive waste. The intent of these papers and reports is to help provide input to define and assess possible approaches for the long-term management of used nuclear fuel and to contribute to an informed dialogue with the public and other stakeholders. The papers and reports currently available are posted on NWMO's website **(www.nwmo.ca)**. Additional papers may be commissioned.

The topics of the papers can be classified under the following headings:

1. Guiding Concepts – describe key concepts, often used in the exploration of difficult public policy issues, which might help guide and inform our examination and assessment of approaches by suggesting important questions for the study to ask and answer.

2. Social and Ethical Dimensions - suggest social and ethical dimensions of managing radioactive waste for the purpose of promoting broader dialogue on these important considerations.

3. Health and Safety – provide information on the status of relevant research, technologies, standards and procedures to reduce the radiation and security risk of managing radioactive waste.

4. Science and Environment – provide information on relevant scientific and environmental research, including the status of our understanding of the biosphere and geosphere.

5. Economic Factors - provide insight into the economic factors and financial requirements for the long-term management of used nuclear fuel.

6. Technical Methods - provide general descriptions of the three technical methods to be studied for the long-term management of used nuclear fuel as defined in the *Nuclear Fuel Waste Act*, as well as other possible methods and related system requirements.

7. Institutions and Governance - outline the current relevant legal, administrative and institutional requirements applicable to the long-term management of used nuclear fuel in Canada, including legislation, regulations, guidelines, protocols, directives, policies and procedures of various jurisdictions.

8. Workshop Reports – provide information on the outputs and outcomes of some NWMO engagement activities including discussions and expert workshops.

The following list below summarizes the title, author, and objective of each of the current papers and reports.

1. GUIDING CONCEPTS

STREAM	PAPER #	TITLE	AUTHOR(S)	OBJECTIVE
Guiding Concepts	1-1	Sustainable Development and Nuclear Waste	David Runnalls MB CAN	Discussion of what the concept of "sustainable development" means, how this concept applies to the long-term management of used nuclear fuel, and the implications for used fuel management decision-making.
	1-2	The Precautionary Approach to Risk Appraisal	Andy Stirling University of Sussex UK	Discussion of what the concept of "precautionary approach" means, how this concept applies to the long-term management of used nuclear fuel, and the implications for used fuel management decision-making.
	1-3	Adaptive Management in the Canadian Nuclear Waste Program	Kai N. Lee Williams College USA	Discussion of what the concept of "adaptive management" means, how this concept applies to the long-term management of used nuclear fuel, and the implications for used fuel management decision-making.
	1-4	Nuclear Waste Management in Canada: The Security Dimension	Franklyn Griffiths University of Toronto ON CAN	Discussion of what the concept of "security" means, how this concept applies to the long-term management of used nuclear fuel, and the implications for used fuel management decision-making.
	1-5	Risk and Uncertainty in Nuclear Waste Management	Kristen Shrader-Frechette University of Notre Dame USA	Discussion of what the concepts of "risk" and "uncertainty" mean, how these concepts apply to the long-term management of used nuclear fuel, and the implications for used fuel management decision-making.
	1-6	Thinking About Time	Stewart Brand The Long Now Foundation CA USA	Discussion of the concept of time, particularly thinking about very long time frames and responsibility.
	1-7	Drawing on Aboriginal Wisdom	Joanne Barnaby Hay River, NT CAN	Discussion of traditional knowledge and the importance of drawing on the wisdom that would come from understanding the role that traditional knowledge could play in the work of the NWMO.

2. SOCIAL AND ETHICAL DIMENSIONS

STREAM	PAPER #	TITLE	AUTHOR(S)	OBJECTIVE
Social and Ethical Dimensions	2-1	Ethics of High Level Nuclear Fuel Waste Disposal in Canada: Background Paper	Peter Timmerman York University ON CAN	Discussion paper suggesting ethical issues to be addressed in decision making on long-term management of used nuclear fuel.
	2-2	Social Issues Associated with the Atomic Energy of Canada Limited Nuclear Fuel Waste Management and Disposal Concept	Mark Stevenson MAS Consulting ON CAN	Overview of the social issues raised by participants during the Seaborn Panel hearings concerning the deep geological disposal (AECL) concept
	2-3	Social Issues Associated with High Level Nuclear Waste Disposal	Maria Paez-Victor Victor Research ON CAN	Discussion paper suggesting social issues to be addressed in decision making on the long-term management of used nuclear fuel
	2-4	Long-term Management of Nuclear Fuel Waste – Issues and Concerns Raised at Nuclear Facility Sites 1996 - 2003	Chris Haussman & Peter Mueller Haussman Consulting ON CAN	Overview of key issues and concerns regarding long-term management of used nuclear fuel raised by the public, affected communities and key stakeholders during recent reactor site environmental assessments.

3. HEALTH AND SAFETY

STREAM	PAPER #	TITLE	AUTHOR(S)	OBJECTIVE
Health and Safety	3-1	Status of Radiological Protection Technologies and Operational Procedures related to High-level Radioactive Waste Management (HLRWM)	Candesco Research Corporation ON CAN	Overview of the current status of radiological protection technologies and operational procedures related to high-level radioactive waste management in Canada.
	3-2	Human Health Aspects of High-level Radioactive Waste	John Sutherland Edutech Enterprises NB CAN	Overview of the human health aspects of high-level radioactive waste.
	3-3	Status of Canadian and International Efforts to Reduce the Security Risk of Used Nuclear Fuel	SAIC ON CAN	Overview of the current status of Canadian and international efforts to reduce the security risk of used nuclear fuel.

4. SCIENCE AND ENVIRONMENT

STREAM	PAPER #	TITLE	AUTHOR(S)	OBJECTIVE
Science and Environment	4-1	Status of Biosphere Research related to High-level Radioactive Waste Management (HLRWM)	ECOMatters MB CAN	Overview of biosphere research undertaken in relation to HLRWM.
	4-2	Charatcterizing the Geosphere in High-level Radioactive Waste Management (HLRWM)	Jonathan Sykes University of Waterloo ON CAN	Overview of geosphere research undertaken in relation to HLRWM.

5. ECONOMIC FACTORS

STREAM	PAPER #	TITLE	AUTHOR(S)	OBJECTIVE
Economic Factors	5-1	Economic Regions Defined in the *Nuclear Fuel Waste Act*	Richard Kuhn University of Guelph Brenda Murphy Wilfred Laurier University ON CAN	Overview of the economic regions as defined in the NFWA in relation to radioactive waste management in Canada.
	5-2	Status of Financing Systems for High-level Radioactive Waste Management (HLRWM)	GF Energy, LLC Washington DC USA	Status report on current financing systems in selected countries for the future safe management of used nuclear fuel.
	5-3	Considerations for the Economic Assessment of Approaches to the Long-term Management of High Level Nuclear Waste	Charles River Associates ON CAN	Preliminary discussion on economic questions that need to be addressed respecting the management of used nuclear fuel.

6. TECHNICAL METHODS

STREAM	PAPER #	TITLE	AUTHOR(S)	OBJECTIVE
Technical Methods	6-1	Status of Reactor Site Storage Systems for Used Nuclear Fuel	SENES Consultants Ltd ON CAN	Overview of the status of reactor site storage systems for used nuclear fuel.
	6-2	Status of Centralized Storage Systems for Used Nuclear Fuel	Mohan Rao & Dave Hardy Hardy Stevenson and Associates ON CAN	Overview of the status of centralized storage systems for used nuclear fuel.
	6-3	Status of Geological Repositories for Used Nuclear Fuel	Charles McCombie McCombie Consulting Switzerland	Overview of the status of geological repositories for used nuclear fuel.
	6-4	Status of Used Fuel Reprocessing, Partitioning and Transmutation	David Jackson David Jackson & Associates ON CAN	Overview of the status of nuclear fuel reprocessing, partitioning and transmutation of used nuclear fuel.
	6-5	Range of Potential Management Systems for Used Nuclear Fuel	Phil Richardson & Marion Hill Enviros Consulting Ltd UK	Overview of the range of potential management systems for used nuclear fuel.
	6-6	Status of Transportation Options for High-level Radioactive Waste Management (HLRWM)	Wardrop Engineering Inc ON CAN	Overview of the current status of transportation systems for HLRWM.
	6-7	Status of Storage/Disposal Containers for High-level Radioactive Waste	Kinectrics ON CAN	Overview of the current status of storage, disposal and transportation containers for HLRWM.

7. INSTITUTIONS AND GOVERNANCE

STREAM	PAPER #	TITLE	AUTHOR(S)	OBJECTIVE
Institutions and Governance	7-1	Status of the Legal and Administrative Arrangements for Waste Management in Canada	OCETA (Ontario Centre for Environmental Technology Advancement) ON CAN	Compendium of significant legislation, regulatory documents, treaties, guidelines, and plans which apply to waste management in Canada.
	7-2	Status of the Legal and Administrative Arrangements for Low-level Radioactive Waste Management (LLRWM) in Canada	Paul Rennick Rennick & Associates ON CAN	Compendium of significant legislation, regulatory documents, treaties, guidelines, and plans which apply to low-level radioactive waste management in Canada.
	7-3	Status of the Legal and Administrative Arrangements for High-level Radioactive Waste Management (HLRWM)	Mark Madras & Stacey Ferrara Gowling Lafleur Henderson LLP ON CAN	Compendium of significant legislation, regulatory documents, treaties, guidelines, and plans which apply to the long-term management of spent nuclear fuel in Canada.
	7-4	Legal and Administrative Provisions for Radioactive Waste Management within the North American Free Trade Agreement (NAFTA)	Aaron Cosbey BC CAN	Assessment of the potential impact of NAFTA on radioactive waste management.
	7-5	Status of Canadian Expertise and Capabilities related to High-level Radioactive Waste Management (HLRWM)	George Bereznai UOIT (University of Ontario Institute of Technology) ON CAN	Status report on current Canadian expertise and capabilities, as well as future requirements, for the safe long-term management of spent nuclear fuel.

8. WORKSHOP REPORTS

STREAM	PAPER #	TITLE	AUTHOR(S)	OBJECTIVE
Workshop Reports	8-1	Environmental Aspects of Nuclear Fuel Waste Management	Robert W. Slater Coleman, Bright & Associates Chris Hanlon Patterson Associates ON CAN	Discussion on the key environmental questions that need to be addressed respecting the management of used nuclear fuel.
	8-2	Technical Aspects of Nuclear Fuel Waste Management	McMaster Institute for Energy Studies McMaster University ON CAN	Discussion on the key technical questions that need to be addressed respecting the management of used nuclear fuel.
	8-3	Drawing on Aboriginal Wisdom – A Report on the Traditional Knowledge Workshop	Joanne Barnaby Joanne Barnaby Consulting Hay River, NT CAN	Report on the Traditional Knowledge Workshop held on September 24-25, 2003 in Saskatoon, SK.
	8-4	Community Dialogue: Report of the Planning Workshop	Glenn Sigurdson CSE Consulting Inc.	Report on the Community Dialogue Planning Workshop held October 7-8, 2003 in Toronto, ON designing ways to facilitate effective and responsive dialogue at the community level.
	8-5	Scenarios Workshop Report – Looking Forward to Learn – Future Scenarios for Testing Different Approaches for Managing Used Nuclear Fuel in Canada	Global Business Network (GBN)	Report on the series of four workshops held between June and October 2003 envisioning the future conditions to be faced in managing used nuclear fuel.