NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

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NWMO BACKGROUND PAPERS
5. ECONOMIC FACTORS

5-4 ECONOMIC AND FINANCIAL ASPECTS OF THE LONG-TERM MANAGEMENT OF HIGH-LEVEL NUCLEAR WASTE: ISSUES AND APPROACHES

Charles River Associates Canada Limited

NWMO Background Papers

NWMO has commissioned a series of background papers 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 background papers is to provide input to defining 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 currently available are posted on NWMO's web site. Additional papers may be commissioned.

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

1. **Guiding Concepts –** describe key concepts which can help guide an informed dialogue with the public and other stakeholders on the topic of radioactive waste management. They include perspectives on risk, security, the precautionary approach, adaptive management, traditional knowledge and sustainable development.
2. **Social and Ethical Dimensions** - provide perspectives on the social and ethical dimensions of radioactive waste management. They include background papers prepared for roundtable discussions.
3. **Health and Safety –** provide information on the status of relevant research, technologies, standards and procedures to reduce radiation and security risk associated with radioactive waste management.
4. **Science and Environment –** provide information on the current status of relevant research on ecosystem processes and environmental management issues. They include descriptions of the current efforts, as well as the status of research into 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 methods for the long-term management of used nuclear fuel as defined in the NFWA, as well as other possible methods and related system requirements.
7. **Institutions and Governance** - outline the current relevant legal, administrative and institutional requirements that may be applicable to the long-term management of spent nuclear fuel in Canada, including legislation, regulations, guidelines, protocols, directives, policies and procedures of various jurisdictions.

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Executive Summary

As the Nuclear Waste Management Organization (NWMO) proceeds to its next stage for studying alternative approaches to the long-term management of Canada's high-level nuclear waste, it must grapple with a broad range of issues across several perspectives. Economic and financial matters form one aspect of the NWMO's work going forward.

This paper attempts to assist the NWMO and its advisors in dealing with these issues by categorizing the relevant economic and financial considerations in a useful manner. In preparing this document we have reviewed materials from agencies with waste management responsibilities in a number of other countries, papers from international organizations such as the International Atomic Energy Agency (IAEA), submissions to the Seaborn panel and other materials from stakeholder parties in Canada, relevant Canadian statutes, regulations, and policy documents, and other background materials prepared for the NWMO.

We believe it is useful to conceptualize the issues as falling into three major categories, which parallel major policy objectives and statutory and regulatory requirements faced by the NWMO.

The first major category relates to the "polluter pays" principle and the objective of ensuring that undue cost burdens do not fall on future generations. These issues are focused on the identification and estimation of waste management costs to ensure that sufficient funds will be available to meet cost liabilities associated with nuclear waste management in the future. The key conclusions in this regard are that a comprehensive approach should be taken to identifying cost factors, and a conservative approach should be employed in estimation.

The second major category of issues surrounds the comparison of alternative waste management approaches, particularly in terms of making efficient and effective use of resources, and ensuring that the distribution of benefits and costs in any approach is equitable. The previously noted conclusions regarding comprehensiveness and conservatism apply here as well, but it is also important to note the limitations inherent in some of the analytical tools that could be employed.

Finally, the last major category is concerned with the arrangements through which waste management approaches may be financed, recognizing that funds that are already being collected now will be used to cover costs that may not be incurred for decades, or even centuries.

The main goal of a successful financing system is its ability to meet the estimated liabilities in the face of many uncertainties and very long timelines, fairness in allocating costs to the producers of the waste, and flexibility to respond to potential changes in the factors that may affect the waste management costs. The regulatory structures and practices currently in place in Canada strive to meet these goals; the challenge going forward will be to ensure that this continues as alternative waste management approaches are considered and compared and one is ultimately chosen.

The final section of this paper also includes an examination of nuclear waste management approaches elsewhere. Looking at other countries facing waste management issues similar to Canada's, there are several themes that appear consistently, albeit with some variation in detail. These include:

- Adhering to the "polluter pays" principle in determining aggregate funding requirements
- Building conservatism into costing – and hence funding requirement – estimates
- Making waste generators (nuclear utilities) responsible for contributing the vast majority of fund assets
- Keeping financial and legal liability for high-level waste in the hands of the waste producer until it is accepted for long-term management
- Ensuring that management of funds is at arm's length from the funds' contributors, with supervision from the government and independent audits
- Taking a conservative approach to fund management, i.e., trading a higher potential return for a more secure preservation of capital, coupled with increased liquidity, by investing substantial portions of assets in low-risk instruments

1. Introduction

1.1. OBJECTIVES OF THIS REPORT

In pursuit of its mandate to select and develop a preferred approach for the long-term management of high-level nuclear waste, the Nuclear Waste Management Organization wishes to explore evaluation criteria and decision-making processes from a variety of perspectives and with input from multiple disciplines, including economics.[1]

We have reviewed documents from a variety of sources – a number of national organizations that deal with various aspects of nuclear waste management issues in other countries, international bodies such as the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA) (a specialized agency within the Organization for Economic Cooperation and Development (OECD)), and a diverse range of interested Canadian parties and stakeholders.

This review has focused on identifying economic and financial issues that these parties have raised or addressed with regard to the long-term management of high-level nuclear waste. This paper defines and categorizes these issues and notes the variety – or similarity as the case may be – of ways in which different agencies and groups view and plan to address them.

The goal is to provide a document that will be useful to the NWMO as it continues its progress towards a November 2005 recommendation to the Minister of Natural Resources (the Minister) by setting out a broad range of economic and financial issues and some examples of possible approaches to them, but without prejudging any actions, decisions, or recommendations that the NWMO may arrive at in the coming months.

1.2. STRUCTURE OF THE REPORT

Following this introductory section, Section 2 provides a high level overview as to how economic and financial issues related to the long-term management of high-level nuclear waste can be categorized. One distinction is made between issues that tend to fall within the domain of multiple disciplines, including economics, versus issues that generally are considered to be within the sphere of technical specialists. A second categorical distinction is made in terms of broad subject matter and policy focus, and is followed up in more detail in the remaining sections of the document.

Section 3 focuses on the "polluter-pays" principle and the objective of ensuring that future generations are not burdened unfairly with costs related to the management of waste produced by their predecessors by examining the identification and estimation of costs.

Section 4 discusses issues that arise in the economic comparison of alternative waste management approaches.

Section 5 focuses on the financing of waste management approaches, and discusses approaches taken by a number of foreign waste management organizations in addressing these issues.

An appendix lays out the legislative and regulatory provisions related to economic and financial issues surrounding the long-term management of high-level nuclear waste in Canada.

2. Overview of Economic and Financial Issues

An undertaking as massive and complex as managing high-level nuclear waste over the long-term presents a long list of issues that must be addressed. Even within the narrower subset of economic and financial issues, there are myriad questions to be considered. This paper attempts to identify key economic and financial issues, categorize them in a useful manner, and provide an indication as to how various other agencies and interested parties around the world are viewing and addressing them.

2.1. BROAD THEMES IN ECONOMIC AND FINANCIAL ISSUES

At the highest level, the economic and financial issues at play can be divided into two themes: issues that fall into the intersection of economics, ethics, philosophy, and politics; and issues that are of a more technical, mechanical, or practical nature. As an example of the former category, the question "who should pay the costs of implementing a long-term waste management strategy?" is one that practitioners of several disciplines, including economics, would view as being within their domains. A related, but more technical, question is "how do we ensure that the necessary funds will be in place to cover costs incurred decades, or even centuries, from now?"

It is unnecessary to classify all issues and questions going forward strictly into one of these two categories, but it is useful to bear in mind that some matters will be particularly well-suited to discussion and analysis by practitioners of multiple disciplines – recognizing that there sometimes will be a need to integrate and reconcile diverging points of view, while others may be handled best through delegation to technical specialists with focused expertise.

2.2. CATEGORIZING ECONOMIC AND FINANCIAL ISSUES

From another perspective, economic and financial issues can be classified by broad subject matter and policy focus. Below we discuss these issues in terms of three categories.

There are many possible ways to organize one's thinking about the economic and financial issues relevant to the long-term management of high-level waste, but the three categories identified below seem useful because they parallel well with major policy objectives and issues that the NWMO, and ultimately the Government of Canada, will have to address. Similarly, they parallel well with the statutory and regulatory requirements identified in the Appendix. Table 1 identifies these linkages, with discussion of the three categories following thereafter.

Table 1 – High-Level Summary of Economic and Financial Issues

Policy Objective	Broad Category of Economic/Financial Issues	More Detailed Considerations
Ensuring intergenerational equity and adherence to the "polluter pays" principle (Consistent with IAEA *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*)	Have costs (and concomitant funding requirements) been fully and appropriately identified?	Have all relevant costs been considered? Has estimation uncertainty been addressed appropriately? Have cost burdens been attributed correctly?
Identifying optimal waste management approach (Consistent with section **12**. of the *Nuclear Fuel Waste Act*)	How do alternative waste management approaches compare in economic terms? (Recognizing that the economic perspective is only one criterion among many for decision-making)	How do approaches compare in cost-benefit or cost-effectiveness terms? How are costs and benefits distributed across groups, regions, generations, etc., under different approaches? What other economic impacts are generated through each approach?
Ensuring adequacy and sustainability of funding mechanism (Consistent with sections **9**., **10**., **11**., and **13**. of the *Nuclear Fuel Waste Act*)	How should the costs of implementing a waste management approach be financed?	How will funds be raised and invested? What financial risks must be managed? What institutional challenges arise given the long-term nature of the issues?

One set of issues is important with regard to the "polluter-pays" principle that is central to the policies that Canada has adopted for nuclear waste management and the parallel objective of intergenerational fairness, that is, ensuring that future generations are not unfairly burdened with costs related to the management of nuclear waste created long before their lifetimes. Starting from the self-evident premise that any waste management approach will have associated – and significant – costs, a first category of issues is the *identification* of costs.

2.2.1. Cost Identification

As discussed later in this document, cost identification leads into such issues as determining:

- How to account for the appropriate range of costs?

  A full accounting will include all the direct and indirect costs of designing and implementing a waste management approach, as well as potential avoided costs[2] under that approach.

- How to estimate unknown costs?

  Recognizing the difficulty in estimating costs far into the future, one must determine what safety margins should be built into cost estimates and what degree of "stress testing" is prudent.

- How to properly attribute cost burdens to different parties?

  So as to properly address questions of externalities and transfers, it is important to identify who is creating certain costs and who, under different scenarios, would bear those costs. Today's consumers of nuclear energy receive the benefits of that electricity, and in so doing create nuclear waste and the cost burden of dealing with it; waste management options involving the transportation of waste, for example, may create cost externalities that are imposed on communities along the transportation route. The identification of such cost burdens and externalities, and possible means of alleviating costs that otherwise would fall unfairly on certain groups, are also important issues.

2.2.2. Cost Comparison

A second broad category of economic questions is those aimed at *comparison* of alternative waste management approaches.

- How do alternative approaches compare in terms of costs and benefits, both in terms of magnitude and in terms of risk and uncertainty?

  Further to the first category discussed above, here both costs and benefits would of course need to be identified. At a more detailed level there is the question of how the comparison is to be done. Is the approach with the greatest net benefit the economically preferred choice? Is it instead the one that provides the greatest ratio of benefits to costs? Would an approach with a lower expected net benefit but a low variance around that expected value be preferred to an approach with a higher value of expected net benefits but that also had a high variance around that value?

- How do alternative approaches compare in terms of distributional consequences across regions, societal groups, and generations?

  For example, long-term retrievable storage approaches will provide future generations with the benefit of the option to make additional choices based on improved knowledge and technology, but these benefits may come at the expense of higher design and construction costs for the current generation who will build the storage facility. As another example, the choice of geological disposal in the Canadian Shield will have significant effects on communities near and on the route to the disposal location, while at the same time removing costs and risks for those residing near reactor sites once the waste has been transported.

- How do alternative approaches compare in terms of economic impacts such as employment creation or increased economic activity in areas that traditionally have shown poor economic performance?

  Some waste management approaches may have positive side effects such as bringing new jobs to economically depressed areas or providing the opportunity for workers in certain areas to develop improved skills. Also, different waste management approaches could have varying impacts on parties such as the nuclear industry itself. The choice of a higher-cost waste management approach could lead to a reduced share for the nuclear sector in Canadian electricity markets (as nuclear energy would then become less price competitive with other energy sources), with such potential effects as higher retail electricity prices, more greenhouse gases or airborne pollutants in the atmosphere, reduced reserve margins on the electricity grid(s), and greater potential for brownouts or blackouts. (But one must recognize that a host of other factors also will influence retail electricity prices, air pollution, reserve margin adequacy, and the potential for grid failures.) An understanding of these impacts may be useful in addition to all the other decision criteria (ethical, technical, environmental, etc., plus other economic and financial criteria) used in the comparison of alternative waste management approaches.

Answers to these questions are necessary to identify the relative economic efficiency of waste management approaches – how can Canadian society best use its scarce resources to achieve its objectives for the long-term management of high-level nuclear waste, and to identify equity considerations – is the distribution of costs and benefits for a given waste management approach fair?

2.2.3. Financing Adequacy and Sustainability

A third broad category includes questions surrounding the adequacy and sustainability of financing for waste management approaches.

- How will funds be raised, invested, and sustained between now and the time when costs actually will be incurred?

  Determinations are required regarding from whom will funds be drawn, and by what mechanism, and how the funds will be managed to ensure that there is sufficient money on hand to meet the full range of future cost requirements.

- What types of risk are present and how are they best mitigated?

  For long-term nuclear waste management approaches, strategies must be determined regarding such financial risk factors as interest rate risk, credit risk, liquidity risk, inflation risk, market risk, and currency risk.

- Considering the very long time frames involved, what institutional issues arise regarding the management and control of these funds?

  Various types of institutional failures could compromise the adequacy or sustainability of funding mechanisms.

Answering these questions is critical to ensuring that plans developed today can actually be implemented tomorrow, and to avoiding the placement of undue cost burdens on future generations.

The following sections of this report discuss each of these three broad categories, delve deeper into the more detailed issues and questions that naturally flow from the higher level ones, and identify views and approaches taken to these issues by various agencies and interested parties.

3. Cost Identification and Sustainable Funding

For any country with a substantial nuclear power sector, like Canada, the costs of long-term waste management approaches will be significant. Given the complexity of the primary task of designing, building, and implementing a waste management approach, the many important indirect factors to be considered, and the extremely long time frame for execution, a complete specification of all relevant cost issues is no simple exercise.

As noted above, the policy objective in focus in this section is ensuring intergenerational equity and adherence to the "polluter pays" principle (and in parallel, funding adequacy for the implementation of a waste management approach) through thorough cost identification. We have broken the task of cost identification into a number of dimensions. Table 2 provides a summary of these cost dimensions. The subsections that follow the table expand on these dimensions: comprehensiveness, scope, and uncertainty.

Table 2 – Summary of Cost Dimensions

Cost Dimension	Key Questions and Concerns
Comprehensiveness of identified cost factors	Has a complete life-cycle costing approach been taken in identifying the direct costs of implementing waste management approaches? Have cost factors been comprehensively identified so as to ensure that future generations are not unfairly burdened with costs overlooked today?
Cost Scope Volume and nature of high-level waste to be managed Time-lines	Has there been careful consideration of the potential volume and nature of waste that ultimately must be managed? Have prudent assumptions been made regarding time-lines for implementation of the waste management approaches? (And what discount rate should be used when considering future cost streams?) Have prudent decisions been made about building optionality and scalability into design plans?
Uncertainty	Has appropriate conservatism been built into all the factors contained in cost estimates? Have events with generally low probability of occurrence but potentially significant cost effects been considered adequately? Have cost models been subjected to appropriate statistical "stress tests"?

3.1. COMPREHENSIVENESS: "POLLUTER-PAYS" AND LIFE-CYCLE COSTING APPROACHES

Canada and many other countries have embraced the "polluter-pays" principle with regard to nuclear waste management.[3] This principle ensures that the financial burden of managing nuclear waste is borne by those who enjoyed the benefits of the electricity production that resulted in the creation of the waste; put another way, it ensures that future generations are not saddled with costs that are by-products of benefits enjoyed only by the current generation.

As discussed more fully in section 5, Canada and other countries are striving to establish sustainable financial mechanisms now to guarantee that the required funds will be in place as costs are incurred over the coming decades and beyond. To ensure that future generations are not burdened with funding shortfalls, it is critical that the costing basis upon which funding requirements are determined is comprehensive. Thus it is critical that a true life-cycle costing approach be used, including:[4]

- processing and packaging costs of spent fuel before shipment to retrievable storage or permanent disposal facilities;
- development and construction costs of storage/disposal facilities;
- transportation costs, from the reactor facility through to the ultimate disposal location, including any interim storage stops in between;
- interim storage costs between current on-site storage and eventual disposal, as applicable;
- costs of depositing the waste in the disposal site;
- monitoring and security; and,
- costs of ultimately closing and decommissioning the disposal site.

This eight-bullet list is a gross simplification of the range of costs involved in the management of high-level waste. Each one of these items would require a multitude of separate line items in a true project budget. The key point is that a life-cycle costing approach is important to achieving the aims of the "polluter-pays" principle.

In addition to the costs associated with activities like constructing waste storage/disposal facilities, transporting waste to these facilities, depositing the waste in the facilities, etc., there potentially are other items to be considered and accounted for in the calculation of costs and the funds required to cover those costs over the long term.

Some countries have considered forms of financial compensation for the regions that eventually will host long-term waste management facilities. In Canada, the *Nuclear Fuel Waste Act* requires that implementation plans for proposed waste management approaches must include "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." To be comprehensive, any costs associated with these means must also be considered.

3.2. COST SCOPE FACTORS

Beyond the need to think comprehensively in terms of identifying direct cost items, there also are a number of fundamental scope factors to consider.

3.2.1. Waste Volume

First, what volume of waste must ultimately be disposed of? The answer to this question depends on a number of variables, including the intensity with which Canada's nuclear reactor fleet is operated going forward, the eventual shutdown date of each reactor, and, potentially, the degree to which pre-disposal processing of spent fuel bundles may impact the nature and volume of high-level waste that requires long-term management.

This uncertainty over waste volumes raises the question of the degree of "volume safety margin" that should be built into design plans and cost estimates; put another way, the question is the degree to which options to alter the scale of the long-term management solutions could and should be built into the design plans, and accounted for in cost estimates. Plans, estimates, and budgets that do not reasonably account for the full volume of high-level waste that may have to be managed over the long term run the risk of subjecting future generations to undue cost burdens.

3.2.2. Time-Lines

Another broad scope factor is the implementation time-line for a waste management solution. For example, AECL environmental impact studies produced in the early 1990s envisaged a time-line on the order of 90 years for the complete implementation of a deep geological disposal approach, culminating in the final decommissioning and closure of the disposal site.[5] There is an argument, however, that it would be inappropriate to implement such an irreversible solution, and that the ethically appropriate solution at this time is monitored, retrievable storage, combined with research to find a disposal or transmutation approach that better protects future generations from possible risks. This and other staged approaches, in which waste is held in some form of retrievable storage for a substantial period of time or in which waste is deposited into a permanent disposal facility but decommissioning and closure of that facility is delayed, result in a cost profile that of course differs from a solution that seeks to fully implement a permanent disposal approach as quickly as possible.

This paper does not attempt to consider the pros and cons of, or the cost differences between, these broad approaches; rather, it simply strives to point out that a decision to implement a fast-as-possible permanent disposal solution will have different cost implications than will a decision to implement some sort of staged, multi-option solution, and that the full range of cost possibilities should be considered in the development of funding solutions.

3.2.3. Discount Rate

Related to the time-line issue is the choice of discount rate used to calculate present values of future cost streams.[6] There is a considerable literature on this issue and this paper does not seek to opine on the choice of an appropriate discount rate, but the profound impact that the choice of discount rate could have on cost calculations – and hence funding requirement calculations – must be recognized. Similarly, assumptions about investment returns on funds that are collected to cover distant future, but substantial, cost streams will have very significant impacts in terms of the calculated deposits required in the near term to ensure the solvency of the waste management fund over the long term. Section 5 of this paper discusses various countries' approaches to these issues.

3.3. UNCERTAINTY IN ESTIMATING COSTS AND FUNDING REQUIREMENTS

The preceding subsections have discussed a wide range of cost factors to be considered for the waste management approaches under review. Given the breadth and complexity of potential cost factors, and the extremely long time-lines at play, any cost estimate will be subject to a great deal of uncertainty. Furthermore, while serious accidents or problems related to any waste management approach may be very low-probability events, the potential associated costs could be significant.

The "polluter-pays" principle and the objective of ensuring that future generations are not confronted with unfair cost burdens suggest that a conservative approach to uncertainty is appropriate. This conservatism is reflected in the requirement by the Canadian Nuclear Safety Commission (CNSC) that Canadian owners of high-level waste base their funding contributions and guarantees on the long-term waste management approach expected to have the highest cost, until such time as a particular waste management approach has indeed been selected. As well, section **13.** (1)(*a*) of the *Nuclear Fuel Waste Act* requires that "natural or other events that have a reasonable probability of occurring" be considered in the estimation of the total costs of waste management. An expansive definition of "reasonable probability" in this context would increase cost estimates, in turn increase funding requirements from today's waste owners, and thereby reduce the chance that future generations would have to bear the cost of some future "natural or other event"; however, the expansive definition approach also increases the likelihood that the generations of Canadians who enjoy the benefits of nuclear power may end up overpaying into waste management funds.

As discussed more fully in section 5 of this document, agencies in other countries have imposed a variety of measures to deal with the uncertainty inherent in any analysis of the cost of long-term waste management and its related funding requirements. In some cases there is a specified schedule for reviewing and updating cost analyses and related funding formulae. Section **16** of the Canadian *Nuclear Fuel Waste Act* contains provisions for annual updates of this nature. Some countries employ specific statistical tools (like Monte Carlo analyses) to analyse the impact of uncertainty in a wide range of factors on overall expected costs and funding requirements. Waste management agencies around the world also employ a variety of investment strategies to deal with the risk and uncertainty that exist in managing the funds that ultimately will be used to cover the cost of the chosen waste management approach.

One must recognize, though, that given the period over which nuclear waste can generate impacts and costs – thousands of years – current generations are quite limited in the degree to which they can model or mitigate uncertainty. Once a time span of hundreds or thousands of years is considered, even basic assumptions about the continuance of society as we know it become suspect.

4. Comparing Waste Management Approaches

The previous section considered issues and questions related to ensuring that a comprehensive view is taken in identifying and estimating the costs associated with any waste management approach.

This section focuses on how alternative waste management approaches may be compared in economic terms, recognizing that economic aspects are only a subset of the various criteria that will be used to assess and ultimately choose waste management approaches.

Section **12** of the *Nuclear Fuel Waste Act* requires the NWMO to examine, at a minimum, three prescribed waste management approaches, and for each approach to compare 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."

The following subsections discuss analytical tools that the NWMO may wish to consider using in conducting economic comparisons of waste management approaches.

4.1. ASSESSING BENEFITS

Section 3 of this document already has discussed identification and estimation of costs (and risk and uncertainty related thereto); before moving on to examining means of economically comparing waste management approaches, it is useful to briefly discuss the measurement of benefits, as well.

As noted in CRA's first paper for the NWMO, economic analyses typically measure benefits as willingness to pay for the outputs of the project. With regard to the long-term management of high-level nuclear waste, the benefits can conceptually be divided into two broad categories:

1. The avoided costs to society (in certain alternatives) both of rationalizing or eliminating the long-term cost of waste management, and of reducing the potential costs of future accidents, etc.

2. The "relief" factor (or the inverse of the "dread" factor), specifically the lessening of public fears and anxieties when the problem is perceived to have been satisfactorily addressed.

As is the case with identifying the costs associated with waste management approaches, there also will be significant uncertainty in estimating certain types of benefits.

4.2. TYPES OF ECONOMIC COMPARISON

From an economist's perspective, there are two main types of comparison relevant to this requirement, welfare analysis and economic impact analysis. These are summarized in Table 3, with more detailed discussion following thereafter.

Table 3 – Summary of Economic Comparisons

Economic Comparisons	Objective
Welfare analysis (i) Aggregate measures - Benefit-cost analysis - Cost-effectiveness analysis	Compare alternatives in terms of how they make use of society's scarce resources, in aggregate – assess economic efficiency
(ii) Benefit-cost effects on particular groups, regions, generations, etc.	Compare alternatives in terms of who gains and who loses, and by how much – assess fairness
Economic impact analysis	Compare alternatives in terms of such measures as employment creation or economic improvement in areas with traditionally poor economic performance – assess impacts

4.3. WELFARE ANALYSIS

4.3.1. Aggregate Measures

Aggregate social welfare analysis seeks to determine how alternative projects (i.e., alternative approaches to waste management) compare in terms of their use of society's scarce resources. Tools such as benefit-cost analysis and cost-effectiveness analysis could be used to assess which approaches make the best use of society's resources in pursuit of waste management objectives.

Benefit-cost analysis can demonstrate whether an approach is economically "positive" or "negative" – that is, whether the benefits derived from the approach exceed the costs of implementing it, as well as define the rank order and net benefits of different approaches.

When ranking alternatives, different criteria are available within the construct of benefit-cost analysis. Is the approach with the greatest net benefit the economically preferred choice (Approach A with benefits of $100, costs of $50, and thus net benefits of $50 is better than Approach B with benefits of $30, costs of $10, and thus net benefits of $20)? Is it instead the one that provides the greatest ratio of benefits to costs (Approach B with a benefit to cost ratio of 3:1 is better than Approach A with a benefit to cost ratio of 2:1)?

In cost-effectiveness analysis, an outcome is defined and alternative approaches are assessed to see which one can produce that outcome at the lowest cost. This tool is appropriate where there are particular difficulties in estimating benefits, which may very well be the case regarding long-term nuclear waste management. Simply as a hypothetical illustration, it is possible that one could conclude that no meaningful difference can be estimated in the aggregate benefits generated by the three waste management approaches listed in the *Act*. Thus cost-effectiveness analysis could be used to determine the preferred approach in terms of aggregate economic welfare: the lowest-cost option would be preferred, because it uses the smallest amount of society's resources to achieve essentially the same outcome.

Uncertainty is also an important factor when considering the use of these different economic tools for comparing alternative waste management approaches. To the extent that benefit or cost factors are inappropriately excluded from analyses, or to the extent that there is uncertainty surrounding the estimated value of these factors, then of course the results of the analysis will be less reliable. In some contexts, though, uncertainty can be dealt with more easily in such comparative analyses. If cost factor X, for example, is common to all three approaches being considered, then the uncertainty surrounding the estimate of cost factor X is irrelevant to the exercise of ranking the three approaches. But again, the uncertainty surrounding cost factor X is very important to estimating the level of funding required to cover the future liability. As well, this uncertainty factor could be very important if cost factor X will have particular impacts on a group or region of special interest.

The degree of uncertainty itself may be an important comparative criterion. For example, benefit-cost analysis could show that one approach has expected net benefits of $100, but with a range of uncertainty of plus or minus 40 percent, while another approach may have a lower expected net benefit of $90, but with a range of uncertainty of only plus or minus 10 percent: a risk-averse decision-maker may choose the second approach because of the smaller risk of a much lower net benefit value.

The consideration of option values is also important in comparative economic analyses. An implementation plan with few opportunities for modification over time may appear less costly than a more complex plan that builds in a number of options for redesign. With the former approach, there also may be a benefit in reducing the risk associated with possible future institutional failures, but there is a different additional risk of locking into an irreversible mistake or foregoing the opportunity for a far superior solution in the future. Conversely, the latter approach requires greater reliance on future institutional stability, but provides more opportunities to avoid and correct errors and to benefit from future positive developments, such as technological breakthroughs.

4.3.2. Distributional Measures

In conducting social welfare analyses, consequences for particular subsets of society, different regions, or current and future generations also may be examined where these distributional effects are of interest to decision-makers.

For example, long-term retrievable storage approaches would provide future generations with the benefit of the option to make additional choices based on improved knowledge and technology, but these option benefits may come at the expense of higher design and construction costs for the current generation who will build the storage facility. As another example, the choice of geological disposal in the Canadian Shield would have effects on communities near and on the route to the disposal location, while at the same time removing costs and risks for those residing near reactor sites once the waste has been transported away.

At one level, these gains and losses can simply be identified in the process of conducting a benefit-cost analysis, so that decision-makers will have this additional information when choosing among alternative approaches; to the extent that a distribution of gains and losses in an approach is judged to be unfair, that approach can be rejected. It also is possible to establish weighting schemes at the outset of the analysis to favour or protect certain groups and then rely more mechanically on the outcome of benefit-cost analysis in ranking approaches. For example, costs that would be borne by some group identified for special consideration could be increased by some multiplier that would make it mathematically more difficult for approaches that placed significant costs on that group to be ranked highly. However, this type of weighting scheme would still require subjective determinations of the weights or multipliers in the first place, in addition to the more fundamental determination of which groups should be singled out as being of particular concern.

In addition to providing information with which determinations of fairness and equity can be made, distributional assessments are important to the extent that compensation may be required or offered to any party that would suffer losses under a particular waste management approach.

4.4. ECONOMIC IMPACT ANALYSIS

Another tool, economic impact analysis, can be used to assess how different projects will contribute to various measures of economic activity.

Some waste management approaches may have positive side effects such as bringing new jobs to economically depressed areas or providing the opportunity for workers in certain areas to develop improved skills. This example reinforces the importance of recognizing the distinction between economic welfare analyses, like benefit-cost analysis, and economic impact analysis. In benefit-cost analysis, the use of labour in a waste management approach would be classified as a cost – there is an opportunity cost because the labour cannot be used elsewhere in society while it is employed in waste management efforts. Conversely, an analysis of the economic impact of a waste management approach on a particular region might classify the labour used as an economic "plus" – particularly in the case where unemployed or underemployed workers in the region would be converted into full-time workers.

Other impacts of interest could include the overall effect on regional economies as a waste management approach is implemented. Spending on the development and construction of a waste management facility will mean greater levels of income for residents of the region as new jobs are created and more business for suppliers of materials and services, for example. Methodologies like input-output analysis can be used to analyse such regional impacts.

Also, different waste management approaches could have varying impacts on parties such as the nuclear industry itself, as noted previously in section 2.2.2.

4.5. ANALYTICAL LIMITATIONS

In the preceding subsections several tools and methodologies for comparative economic analysis have been discussed. These tools are designed to address important questions and policy considerations, and the findings of such analyses certainly would be of value to the NWMO, and ultimately the Government of Canada, as they assess alternative waste management approaches.

Two points are worth noting here, however. First, economic analyses will form only a small part of the input to be used in the assessment of approaches. Second, given the nature of the issues and the time frames involved, it is unreasonable to expect to have precise black-and-white answers with regard to the noted economic questions. While it may be possible to develop a reasonably comprehensive conceptual listing of pertinent economic factors, many will simply be impossible to quantify, and many of those that can be quantified can still only be estimated to a very coarse level. What these analytical tools may provide, though, is sufficient information to allow some degree of economic ranking of alternative approaches, or in some cases, comfort that different approaches are sufficiently similar in economic aspects that more stock can be placed in the rankings provided by other decision criteria.

5. Financing Waste Management Approaches

The main goal of a successful financing system is its ability to meet the estimated liabilities in the face of many uncertainties, fairness in allocating costs to the producers of the waste, and flexibility to respond to potential changes in the factors that may affect the estimated or actual waste management costs.

Some key issues are summarized below in Table 4.

Table 4 – Financing Issues

Issue	Key Questions
Cost basis	Are cost estimates reasonable, comprehensive, and robust?
Cost allocation	Considering the nature and volume of waste produced by the various owners, and their timelines for delivery to a storage/disposal facility, have costs been allocated fairly across the waste owners?
Funding formula	What levels of further deposits are required from each waste owner and over what timeline?
Scalability/ Adaptability	How will eventualities such as the construction of new nuclear reactors impact cost bases, cost allocations, and funding mechanisms?
Fund stability	What measures can be taken to ensure that funds will be available when required to cover costs incurred in the distant future?

Frameworks have been established across jurisdictions to provide safekeeping and oversight to ensure the availability of funds for long-term nuclear waste management.

This section discusses the issues surrounding funding arrangements for waste management solutions and also provides some comparative information on approaches employed or considered by several developed countries with substantial commercial nuclear programs. These countries are at different stages of developing their financing systems and the activities covered by these systems differ from country to country. There are two general situations: countries who have selected a program and have defined a set of activities (such as geological disposal at a specific site in the U.S.), and those who have not made a decision as to the long-term waste management option, but have started to set aside finds based on some sort of conservative estimate (e.g., France).

As presented in section 5.1, in Canada, legislative provisions have established responsibilities for fund contributions, oversight, and eventual access to the funds. While the NWMO is not therefore required to address these issues, a cross-jurisdictional summary is provided here by way of context, to illustrate that fund management and oversight have been important considerations across countries as they provide for the overarching framework for the long-term management of used nuclear fuel. In the first subsection below, the funding mechanisms currently in place in Canada are reviewed, and future issues and questions to be addressed are discussed. (The appendix discusses the statutory and regulatory frameworks that underpin these funding mechanisms and structures.)

For comparative purposes, the remaining subsections discuss several financial issues related to waste management funds in a general sense and also provide information on approaches taken in a number of other countries. (In some instances decommissioning issues also are discussed, as different countries have different levels of linkages between their decommissioning and waste management regulatory schemes.)

5.1. FUNDING ARRANGEMENTS FOR WASTE MANAGEMENT IN CANADA

5.1.1. Current Status

With the proclamation of the *Nuclear Fuel Waste Act* in November 2002, Ontario Power Generation Inc., Hydro-Québec, the New Brunswick Power Corporation, and Atomic Energy of Canada Limited made initial deposits into trust funds for the future management of nuclear fuel waste, as follows:

- Ontario Power Generation Inc. - $500,000,000
- Hydro-Québec - $20,000,000
- New Brunswick Power Corporation - $20,000,000
- Atomic Energy of Canada Limited - $10,000,000

Thereafter, further annual deposits are required:

- Ontario Power Generation Inc. - $100,000,000
- Hydro-Québec - $4,000,000
- New Brunswick Power Corporation - $4,000,000
- Atomic Energy of Canada Limited - $2,000,000

These annual deposits are required until such time as the Minister approves the new funding formula that will be one of the eventual outputs of the current work of the NWMO (with annual updates). The trust funds are managed by independent financial management companies.[7] Only the NWMO may make withdrawals from the fund, and only for the purpose of implementing the approach to be selected. In addition, the NWMO may withdraw the funds only after the CNSC has issued either a construction or operating licence for the approach approved by the government.

The CNSC requires nuclear licensees to provide financial guarantees related to decommissioning and waste management. Deposits to waste management segregated funds and trust funds are included along with decommissioning funds and commitments in the assessment of whether a licensee has sufficiently addressed all decommissioning and waste management liabilities.

In calculating their liabilities, the CNSC has asked licensees to estimate waste management costs assuming the most expensive of the three options under consideration by the NWMO (until a particular waste management approach has indeed been selected). The licensees have identified deep geological disposal as being the most expensive of the three options, and to date have based their cost estimates, with some adjustments (e.g., revisions to the estimated amount of waste generated), on the AECL estimates prepared for the environmental assessment process in the mid 1990s. The CNSC also reviews supporting assumptions (timing, discount rate, etc.) to ensure that there is an appropriate degree of conservatism.

OPG, for example, did note in its 2003 application to the CNSC for amendments to its operating licences that the timing of eventual reactor shutdown and decommissioning has an impact on cost estimates, as does the timing of the development and implementation of any waste management approach. The discount rate chosen to convert future cost streams into present values also has a strong impact. In its 2002 Annual Report, OPG notes that a 0.25% increase (decrease) in the discount rate would cause a decrease (increase) in its total decommissioning and waste management liability of roughly $500 million.

5.1.2. Future Issues

The NWMO soon will begin its own review of cost estimates of all three approaches listed in the *Nuclear Fuel Waste Act*. The *Act* requires that the NWMO's study on waste management approaches set out a formula for each approach that calculates the required annual funding amount, including explanations for assumptions regarding estimated total costs, the rate of return on trust funds, the life expectancy of reactors, and the amounts the NWMO will receive for waste management services from nuclear fuel waste owners other than OPG, Hydro-Québec, NB Power, and AECL. The study also must set out the breakdown of cost percentages across OPG, Hydro-Québec, NB Power, and AECL, as well as the form and amount of any financial guarantees for waste management they have provided under the *Nuclear Safety and Control Act*.

As discussed in section 3, the NWMO will need to assure itself that the estimated costs for the three approaches listed in the *Nuclear Fuel Waste Act* – and any other approaches that may be under consideration by the NWMO – are reasonable, comprehensive, and robust.

With cost liabilities for each waste owner established, funding amounts and schedules then must be established. Following the selection of a waste management approach, the *Nuclear Fuel Waste Act* requires that the NWMO submit an annual report to the Minister of Natural Resources that decribes financial guarantees that have been provided in the previous year, updates waste management cost estimates, and provides budget forecasts, a funding formula, and required deposit amounts for the next year. The NWMO and the financial institutions that hold the trust funds must provide independently audited financial statements annually.

The estimation of total costs, the allocation of costs across waste owners, and the establishment of a funding formula to ensure that cost liabilities are fully addressed all become more complex issues in the event that waste volumes grow beyond the expected output of Canada's current nuclear reactors. Careful consideration must be given to how eventualities such as the construction of new reactors in Canada will be factored into these analyses.

It also is important to bear in mind that some costs associated with waste management will not be incurred until perhaps many, many years from now – far beyond the range of normal financial analyses. This fact raises questions as to how funds collected in the near(er) term can be protected over the very long term to ensure that they are fully available as required to meet those far-off costs. In addition to the various types of financial risks that must be addressed, there is also the possibility of institutional failures. Investment, management, and governance decisions regarding waste management funds should be made with this long-term perspective in mind.

5.2. FUND STRUCTURES IN OTHER COUNTRIES

5.2.1. Activities Covered by Funds

The financing scheme for long-term management of nuclear waste may be composed of one single-purpose fund, one multiple-purpose fund, or several single-purpose funds. This distinction in structure is mainly administrative in nature, which is a result of several factors.

First, the fund (or funds) may serve different purposes: it (they) may be designed to cover solely waste management costs, or both waste management costs and the costs of decommissioning nuclear reactors. For example, in Switzerland two funds are in place: one to cover decommissioning costs and another one for waste disposal costs,[8] while in Sweden and Finland, one fund is in place to cover the costs of dismantling the nuclear facilities as well as the long-term management of the waste.[9] [10]

Second, in the absence of a centralized fund, utilities may be required to separately accumulate reserves which can later be used to fund waste management and other related activities, in some cases in anticipation of the development of a centralized funding scheme.

In some countries, utilities are responsible for accumulating decommissioning funds independently of the waste management funds. In Belgium, financing of decommissioning activities is separate from the waste management, where the financing mechanisms are established separately for each producer through the waste management organization.[11] In Germany as well, separate reserves are established for decommissioning versus management and disposal of spent fuel.[12]

Even within the waste management costs, various components may be included or excluded. For example, in Japan, the fund is supposed to cover expenses incurred by the implementing body, but only associated with disposal, while the costs of storage and transportation are expected to be borne directly by the utilities.[13]

The distinction also is made as to whether the waste management costs included should be limited to those incurred after the closure of the power plants, or whether they should include those costs incurred during the service life of the reactors (e.g., onsite storage or reprocessing). For example, in Switzerland, waste management costs arising before the end of the service life of the reactors are borne directly by the nuclear power plants.[14]

Finally, historic waste (waste generated prior to the establishment of a coordinated waste management program) may be included in the fund's coverage. In the U.S. the current fund includes a provision for the financing of historic waste. This is also the case in Switzerland, where operators of the plants are required to retroactively pay for the costs accrued before the fund's establishment in 2000, with a deadline for all retroactive payments set for 2005.[15] In Sweden, special fees are collected to cover expenses for the management of nuclear waste from older experimental facilities, as well as for their dismantling.

5.2.2. Valuation Methodologies

Once waste management activities have been identified and their costs estimated, the linkage to funding requirements must be made. There are two principal methodologies for valuing the funding requirement associated with future cost liabilities: present value and current value.

The present value method entails estimating the current cost of a liability, projecting it into the expected time frame, and then discounting to get a present value. In the current value method, one assumes that all costs could be incurred immediately, that is, the value ascribed to a future liability is independent of the time at which the expense will be incurred. (This is equivalent to using the present value method with the discount rate set to zero.) For the same set of cost factors, the current value method will require greater funding contributions to cover all liabilities since none of the factors will be discounted; hence it is a more conservative approach.

Table 5 reports several countries' choices regarding present value and current value approaches.

Table 5 – Valuation Methods by Country

Valuation Method	Country Examples*
Current Value	Finland, Germany, South Korea, United States
Present Value	Belgium, France, Japan, Netherlands, Spain, Sweden, Switzerland, United Kingdom

*As noted in section 5.2.5, several countries (e.g., France, Germany, South Korea, and the UK) are actively reviewing their financing schemes, thus the "current value" and "present value" designations are subject to change.

5.2.3. Fund Contributors

In most countries, the waste generators are responsible for contributing the vast majority of the funds' assets. The only exceptions are the countries in which the government either contributes a portion of the funds or provides a form of guarantee.

For example, in Germany there is an arrangement for government provision of certain costs at Morsleben (the site inherited from East Germany as a result of unification). In the UK, the government has agreed to assume financial responsibility for qualifying liabilities in excess of the assets in the Nuclear Liabilities Fund (NLF).[16] In the U.S., 70 percent of the fund is financed by waste producers, with the remaining 30 percent coming from a separate Department of Energy account. This is due to the fact that a portion of the waste comes from the defence program.

As a general point, there tends to be a single contributor to a fund established solely for reactor decommissioning costs – the reactor owner, whereas there generally are multiple contributors to funds for multi-user undertakings, such as construction and operation of waste management facilities.

5.2.4. Rights and Liabilities

In its paper "Status of Financing Systems for High-Level Radioactive Waste Management (HLRWM)," GF Energy, LLC notes that across the several countries it has surveyed, financial and legal liability for high-level waste generally remains in the hands of the waste producer until it is accepted for long-term management, and under programs for deep geological disposal, title and liability would change to the entity responsible for the repository once that entity has taken physical possession of the waste.[17]

In all systems where advance payments to waste management funds are used, the producers acquire an implicit right to dispose of their waste in the facilities financed by their funds. In Belgium and the Netherlands, there are formal arrangements that ensure the proportional allocation of reserved capacity based on the financial contribution.[18]

It is important to establish a timeline and define contingency provisions associated with the transfer of title and liability of the waste from one entity to another, to avoid additional potential costs. In the U.S., for example, the delay in the implementation of the Yucca Mountain program has resulted in the question of responsibility for extended on-site storage of the waste, with several waste producers pursuing legal action against the Federal Department of Energy (DOE) for having failed to begin accepting the waste.

5.2.5. Basis for Payments

Financing schemes currently in operation in countries with substantial commercial nuclear programs involve some form of advance payment by producers to pay for the costs of designing and constructing waste storage or disposal facilities. Advance payments are made periodically (on an annual basis in many cases), based on the estimates of costs.

Table 6 provides a summary of what various countries use as bases for payments. It is noteworthy that in many countries (France, Germany, South Korea and the UK), the financing schemes are either being developed or under review, so the table illustrates the current situation, which may change in the future.

Table 6 – Basis for Payments into Funds

Country	Basis for Payments
Belgium	• reserved capacity ("fixed costs") • unit of waste delivered ("variable" costs)
Finland	• generating capacity ("fixed" costs) • unit of waste generated (number of canisters or assemblies, or volume-based, "variable" costs)
France *(under review)*	• producer-specific • revenues from electricity production for Eléctricité de France (EdF) and Compagnie Générale des Matières Nucléaires (COGEMA)
Germany *(under review)*	• from public sector budget for publicly owned utilities • revenues from electricity production for privately owned utilities • unit of waste generated (volume-based) for Morsleben[19] repository • unit of waste delivered (for small generators)
Japan	• unit of waste generated (number of canisters) • some utilities transfer the cost to consumers as an explicit portion of electricity rates
Netherlands	• down payment for construction and operation of storage facility, based on percentage of volume reserved by producer
South Korea *(under review)*	• levy on electricity generated from nuclear plants (per kWh) • fee levied on Korea Nuclear Fuel Company (KNFC), who supplies Pressurized Water Reactor (PWR) and CANDU fuel to Korea Hydro and Nuclear Power (KHNP)
Spain	• levy on electricity rate (percentage)
Sweden	• levy on electricity generated from nuclear plants (per kWh, plant-specific) • flat rate (administration, radiation monitoring costs)
Switzerland	• fixed payments based on estimated costs net of revenues generated by the fund
United Kingdom *(under review)*	• fixed payments based on estimated costs, producer-specific • percentage of net cash flows of British Energy Group, plus a deposit in form of corporate bonds (part of proposed restructuring)
United States	• levy on electricity generated from nuclear plants (per kWh)

As the table above illustrates, fees paid by producers into the funds can be based on either the amount of electricity produced by nuclear plants, overall electricity rates, the amount of nuclear waste generated in a given year (i.e., the future liability associated with the waste), or the expected share of the long-term storage or disposal capacity.

In general terms, basing fee contributions on the amount of waste produced is both an equitable and an economically efficient approach: it is equitable in that those who enjoy the benefits of energy from nuclear plants also incur the associated costs, and it is efficient in that the appropriate party faces the incentive to reduce waste production.

Using the amount of electricity produced by a nuclear plant is a reasonable approach as well, since there is presumably a strong correlation between the production of nuclear energy and the production of nuclear waste. However, to the extent that some nuclear operators have better energy production-to-waste production ratios, because of better technology or superior operating practices, then a fee based on energy production may be somewhat more inequitable.

Another potential differentiating factor is the length of time that reactor owners will keep spent fuel on site. If owner A will keep spent fuel on site for five years before it is removed for storage or disposal, that may have different storage/cost implications than is the case for owner B who keeps spent fuel on site for ten years. Treating these two owners equally in terms of required fee contributions could thus be unfair as owner B, by incurring five more years of short-term on-site storage costs at its sole expense and, may require less "room" in the long-term waste management facility due to the changes in the waste's characteristics that have occurred over those five years.

Many countries base part or all of their advance payments on electricity output, through a levy on electricity generation. In most cases, these levies are either directly or indirectly passed through to the final consumer. More specifically, the utilities in Spain collect the fees associated with nuclear waste management from the consumers by means of an explicit percentage applied to the electricity rate, whereas in Sweden the per unit of electricity generated fees are worked into electricity rates paid by the consumers.

In allocating costs among waste producers, some countries make a distinction between "fixed" and "variable" costs. Thus, an attempt is made to either separate the costs that are a function of waste generated from those that are not, or to provide a mechanism for the reservation of capacity in a long-term storage or disposal facility for the waste producers.

For example, in Finland "fixed" costs include R&D, construction of encapsulation plants, repository shafts and part of the tunnels, plus some decommissioning expenditures, while "variable" costs cover mainly canisters and remaining parts of tunnel construction and decommissioning. Correspondingly, "fixed" costs are allocated between the two major producers based on the relative generating capacities, whereas "variable" costs are assigned based on the amount of fuel produced. By separating fixed and variable costs in such a way, this system is designed to reward the producer with greater efficiencies, who manages to produce less waste given a set amount of capacity.

Alternatively, in Belgium, "fixed" costs are charged to each producer according to committed volumes, and, in the case of storage and disposal payments, each producer receives in return a reservation of capacity. "Variable" costs are charged to producers according to actual volumes of waste delivered.[20] Such a system ensures that a producer would conservatively estimate the amount of waste to be generated (and secure the associated funding), in return for a guaranteed portion of storage and/or disposal capacity.

It is also noteworthy that in Belgium and Finland, the funds effectively serve as guarantees. In Belgium, the part of the payments relating to fixed costs is offset against a guaranteed sum. As a result, the producers' guarantees reduce with time. At the end of the contractually agreed period, the waste producers may decide to renew or to terminate the relationship with the waste management organization and upon termination to pay any outstanding share of the fixed costs.[21] In Finland, the scale of the future liabilities for each company is calculated every year based on the assumption that all plants are closed at the end of the year. The fund effectively serves as a guarantee, where the goal is to ensure that at any point in time there are sufficient funds available to take care of the nuclear waste produced up to the moment.[22]

While many countries examined have similarities in their approaches to assigning waste management costs by way of calculating payments into the funds, several jurisdictions have unique features, which are discussed below.

In Germany, the way in which the funds are secured is different for publicly owned versus privately owned operators. The costs associated with the publicly owned facilities (research and prototype reactors) are paid for by the public sector budget, with the federal government bearing most of the burden, while the privately owned utilities accumulate reserves during the period of operation from electricity revenues.[23] Financing of the Morsleben repository is in the form of a fee per cubic metre, which is fixed by contract, with any additional costs being the responsibility of the Federal government.[24] There are special arrangements for small generators, who are required to transport their wastes to storage depots operated by the Federal States and must pay a fee dependent on the amounts of the delivered waste.[25]

Germany's Federal Government decided in 2000 to abandon nuclear energy and modify its waste management policy, pursuing the concept of a single repository for all kinds of waste. As a result, a new cost estimate will be prepared based on the new policy, so that the basis for calculating the contributions into the waste management funds will change as well.[26]

In France, the operators currently have independent funding arrangements, even though no legal requirement exists to ensure this. In the case of Eléctricité de France (EdF), a specific fund was created as part of a contract with the government, where the payments are linked to EdF's revenues from electricity production. In the case of AREVA (an industrial group, majority-owner of COGEMA – a utility), the contributions are made based on COGEMA's revenues.[27] In the case of Atomic Energy Commission (CEA), a dedicated fund was created in 2001 to cover long-term liabilities, including decommissioning. In addition, there are various kinds of contracts between ANDRA (National Radioactive Waste Management Agency) and waste generators, including pre-financing contracts enabling ANDRA to conduct R&D and to cover future expenses relating to the establishment of the storage site or a depository.[28]

France is currently conducting studies in three major research areas: partitioning and transmutation of long lived radionuclides in the waste, evaluation of options for retrievable or non-retrievable disposal in deep geological formations, and study of conditioning processes and long term surface storage techniques.[29] As a result, the basis for calculating payments into the waste management funds will change once the option for long-term management is selected.

The UK government is also on the path of major change in the area of long-term management of nuclear waste. A new organization (Nuclear Decommissioning Authority) will take over the liabilities of state-owned waste producers (British Nuclear Fuels and the UK Atomic Energy Authority) in 2005. In the meantime, the Department of Trade and Industry has established a team (Liabilities Management Unit) to conduct preliminary work to pave the way for NDA. On the commercial side, under the proposed restructuring plan, which is to be completed in 2004, British Energy Group would be obligated to contribute a portion of its net cash flows to a nuclear liabilities management fund. The initial portion would be set at 65%, and would be subject to potential subsequent adjustments.[30]

Some countries have separate arrangements for the historic waste – waste generated prior to the establishment of a nuclear waste management program. In the U.S., the historic waste (generated prior to 1983) is financed through a one-time fee, which can be paid in three different ways: 1) prorated evenly over 40 quarters (including interest), 2) single payment prior to first delivery of spent fuel waste to the repository, or 3) early payment – either prior to June 30, 1985 or two years following contract execution (between utilities and DOE).[31]

5.2.6. Accounting for Risk

There are many uncertainties that are likely to surround the cost estimates driving the funding requirements for long-term management of high-level nuclear waste. It is difficult to estimate both the precise size of the liabilities, as well as their timing. Some of the risks are operational in nature, such as the pace of technological advancements, the amount of the waste to be generated in the future, the cost of labour, etc. Other potential risks include political, environmental, or regulatory developments. For example, a significant technological development could substantially reduce the costs associated with the encapsulation of the waste, as well as potentially accelerate the final disposal process and hence bring forward the liabilities associated with it. On the other hand, future environmental regulations may make certain aspects of permanent storage of nuclear waste more costly and potentially cause a delay in the final implementation of the long-term management plan.

In order to address the risk of underestimating the size of future liabilities, a certain level of conservatism needs to be built into the cost estimates, the funding requirements, or both. This level of conservatism can be achieved in a variety of ways. For example, one would arrive at more conservative estimates of future liabilities by applying the current value method as opposed to the present value method. Alternatively, if the present value method is used, then the choice of discount rate can be conservative to ensure that the estimated size of liabilities is not unduly deflated and the timing of the liabilities is conservatively estimated.[32] As noted previously, the most conservative choice of discount rates for future costs streams – zero – makes the present value and current value approaches identical.

The discount rate assumptions used by various countries in their financing schemes are typically conservative, in the 2-4 percent range.[33] For example, the discount rate used in Japan is 2 percent and is based on the average interest rate of 10-year government bonds over the most recent 5-year period, adjusted for inflation,[34] while in Sweden, an average real rate of return of 4 percent is assumed until 2020 and 2.5 percent thereafter (the post-2020 discount rate is for the fees generated to cover the waste coming from the Studsvik research reactor, where the costs will be incurred sooner).[35] Some countries have considered separate discount rates for the cost and revenue (from contributions by waste producers into the fund) streams, where the discount rate applied to the revenue stream would be higher reflecting additional risk of payment default by waste producers and other uncertainties (such as environmental regulation).[36]

Another potential way to address uncertainty surrounding cost estimates and resulting fund contributions is to generate a distribution of potential costs along with the probabilities associated with the various scenarios. Probability distributions are used as part of cost estimation in some countries. In Sweden, Monte Carlo simulation is employed to provide an estimated distribution of the costs based on different levels of risk.[37] In Belgium, they have chosen to base uncertainty margins on methodologies developed by the Electric Power Research Institute (EPRI) in the United States for estimating the costs of nuclear power plants. Margins are applied to both "project contingencies" and "technological contingencies" and vary in size for different aspects of a project or technogical process: for example, a "final" project estimate would have a contingency factor (X) in the 5% to 10% range; the margin for a new technological process (Y) for which there no comparative data are yet available would be at least 40%. The total uncertainty margin coefficient for an estimate is obtained by combining the two margins ((1+X) * (1+Y)). The Belgian SAFIR 2 report examines two approaches and breaks each into four phases. The uncertainty margin coefficients used for the eight phase estimates range from 1.95 (a margin of 95% above the estimate) to 3.00 (a margin of 200% above the estimate).[38] For purposes of determining financing requirements, a normal distribution around this cost estimate (that includes the uncertainty margins) is generated and the required funding level is set in line with a 90% confidence level, that is, there is a 90% probability that the prescribed funding level will be greater than or equal to the actual financial requirement in the future. This 90% confidence level approach will carry forward for the full time horizon of the waste disposal program. If any excess funds remain at the termination of the project (decades or even centuries from now), they will be redistributed to waste producers based on their proportional shares of historical contributions to the fund; the state will keep the excess funds in the case where the waste producer is no longer in existence.[39]

Another, perhaps less direct, but potentially more effective way to address the risks associated with the size and timing of future liabilities to ensure availability of financial resources is by periodically reassessing the costs and/or the annual contributions into the funds. The fees/payments are typically recalculated annually, to at least keep pace with inflation. For example, in the U.S., the ongoing per unit fee is reassessed regularly, to ensure full life-cycle cost recovery (the fee, however, has remained unchanged even despite the increased cost estimate, partly due to the delay in the implementation of the disposal plan).

In Switzerland, the calculations for the contributions into the fund are reviewed every five years. If the value of the assets in the fund falls 15 percent below or increases 20 percent above the target level, then annual contributions are revised.[40] The annual fees are typically recalculated every three years in Italy taking into account efficiency criteria (annual recalculations are possible if major events occur).[41] The cost estimates and the resulting contributions are also reviewed on a regular basis in Germany to take into account progress in technology.[42] In Japan, the current formula for estimating annual contributions into the fund was established in 2000 and is expected to continue for 15 years.[43]

In order to address the timing risks, conservative assumptions about the timing of the various liabilities can be applied or special provisions can be set up to address such risks as early decommissioning of nuclear reactors. For example, the annual contributions into the fund in Finland are based on the assumption that all plants will be closed at the end of the year. This ensures that the funds are readily available if unforeseen circumstances require early closure and the resulting handling of the waste. Similarly, in Sweden the operators are required to provide guarantees each year to meet the expected size of the liabilities in the event that the reactors are shut down that year.[44]

Other potential ways of addressing various risks, especially those of the unforeseen nature, is by instituting explicit contingency provisions. For example, in Belgium the waste producers have signed contractual guarantees to cover any additional costs not covered by the tariff payments; separately, an "insolvency fund" is employed to cover potential expenses for managing the waste of small producers that have become insolvent.[45]

In Finland, in the case where the producer is no longer capable to contribute to the fund, the government is authorized to take over both the waste and the account of that producer in the Fund. The securities furnished by the producers (which are given to the government and not the fund) guarantee that the fund can return assets to the government in time to compensate for the actual waste management measures incurred – these contingency funds can be up to 20 percent for some cost components. In addition, as a precaution against unforeseen events, supplementary securities covering 10 percent of the assessed liability are provided to the government.[46]

5.3. FUND MANAGEMENT IN OTHER COUNTRIES

The way in which a fund is managed is an important consideration, since it is necessary to ensure the assets are protected to meet the future liabilities associated with the long-term management of the waste, especially given the long-term nature thereof.

5.3.1. Managing Organizations

There are four major types of organizations responsible for the management and oversight of nuclear waste funds: departments or agencies of national governments, designated waste management organizations, waste producers, and independent third-party organizations. Table 7 provides a summary of the functions performed by various organizations in different countries, while Table 8 identifies each organization by its type.

Table 7 – Institutions Responsible for Fund Management and Oversight[47]

Country	Determination of payments into the Fund(s)	Fund oversight	Fund management	Fund auditing	Right to use the funds
Belgium	ONDRAF / NIRAS	Minister of Economic Affairs	ONDRAF / NIRAS using external money managers[48]	Financial Auditing Committee (ONDRAF / NIRAS Board)	Supervisory Committees of funds
Finland	Ministry of Trade & Industry	Ministry of Trade & Industry	Ministry of Trade & Industry	Independent accountants appointed by government	Ministry of Trade & Industry
France *(under review)*	Waste producers, overseen by Ministry of	Ministry of Industry[49]	Waste producers	Waste producers' auditors	ANDRA

	Industry				
Germany	BfS (publicly-owned); waste producers (privately-owned)	BfS (Ministry of the Environment)	BfS (publicly-owned); waste producers (privately-owned)	BfS (publicly-owned); waste producers (privately-owned)	Oberfinanz-direktion ('Higher Financial Authority')
Japan	NUMO	METI, NUMO	RWMFRC	METI, independent accountants	METI
Netherlands	Ministry of Housing, Spatial Planning and the Environment[50]	Ministry of Finance	COVRA	Private accountants[51]	COVRA
South Korea	MOST	MOST	KHNP	Auditor of KHNP, MOST	KHNP
Spain	ENRESA	Oversight & Control Committee (Ministry of Economy and Ministry of Finance)	ENRESA	Inter-Ministerial Committee for Follow-up & Control; independent auditors	Ministry of Economy
Sweden	SKI	SKB, SKI	KAFF	SKI, external auditors	SKI
Switzerland	Management Committee set up by DETEC	Federal Department of Environment, Transport, Energy & Communications	Management Committee set up by DETEC	Government-nominated investment committee, external experts	Management Committee set up by DETEC
United Kingdom	To be determined	To be determined	To be determined	To be determined	To be determined
United States	OCRWM (part of DOE)	OCRWM (part of DOE), Congress	OCRWM (part of DOE)	External auditor (KPMG Peat Marwick)	OCRWM (part of DOE)

Table 8 – Institution Descriptions

Legend for Organization Type: 1 = government department/agency, 2 = waste management organization, 3 = waste producers, 4 = independent third party

Country	Acronym	Name	Type *(see legend above)*
Belgium	ONDRAF / NIRAS	National Agency for Radioactive Waste and Enriched Fissile Materials	2
		Ministry of Economic Affairs	1
Finland		Posiva Oy	2
		Ministry of Trade and Industry	1
France	ANDRA	National Radioactive Waste Management Agency	2
	AREVA	Industrial holding company, single shareholder of COGEMA[52], majority-owned by CEA	3
	CEA	Atomic Energy Commission	1
	EdF	Eléctricité de France	3
Germany	BfS	Federal Office of Radiation Protection, within the Ministry of Environment	1
		Oberfinanz-direktion ('Higher Financial Authority')	1
Japan	RWMFRC	Radioactive Waste Management Funding & Research Centre	4
	NUMO	Nuclear Waste Management Organization	2
	METI	Ministry of Economy, Trade & Industry	1
Netherlands	COVRA	Central Organization for Radioactive Waste (now government-owned)	1/2
		Ministry of Finance	1
		Ministry of Housing, Spatial Planning and the Environment	1
South Korea	KHNP	Korea Hydro & Nuclear Power Co. Ltd., subsidiary of KEPCO (Korea Electric Power Company)	3
	MOST	Ministry of Science & Technology	1
Spain	ENRESA	Empresa Nacional de Residuos Radioactivos, S.A. (Radioactive Waste Management Organization)	2

		Oversight & Control Committee (Ministry of Economy and Ministry of Finance)	1
Sweden	KAFF	Board of the Swedish Nuclear Fund	1
	SKB	Swedish Nuclear Fuel and Waste Management Company	2
	SKI	Swedish Nuclear Power Inspectorate	1
Switzerland	DETEC	Federal Department of Environment, Transport, Energy & Communications	1
United Kingdom	LMU	Liabilities Management Unit (predecessor to NDA, within Department of Trade and Industry)	1
	NDA	Nuclear Decommissioning Authority – to be established	1
United States	OCRWM	Office of Civilian Radioactive Waste Management, within Federal Department of Energy	1

Most countries have ensured that the management of the funds is at arm's length from the funds' contributors. It is also common for the funds to be overseen by a department or agency of the national government. In Sweden, an independent government agency KAFF (the Board of the Swedish Nuclear Waste Fund) administers the fund and underlying securities and reports to the government annually regarding the status of the fund. In other countries, such as the U.S. and Finland, the fund is both managed and overseen by a department of the national government, while independent accountants perform audits of the fund's assets.

In some cases, such as Switzerland, there are several layers of oversight built into the fund's management: the fund's assets are invested by a number of custodian banks and asset managers, which are overseen by an investment committee that formulates and implements investment strategy, selects procedures for custody, asset managers, and auditors, and supervises payment transactions. This investment committee is in turn overseen by a management committee, nominated by the Federal Department of Environment, Transport, Energy and Communications (DETEC), where owners of nuclear plants are entitled to five out of eleven seats.[53]

The two most common types of organizations responsible for determining the payments into the funds are departments of national governments and designated waste management organizations.

5.3.2. Withdrawals

In most countries, the implementing organization has the right to withdraw the funds, based on a budget approved by the government.

In the U.S., the fund is held by the Federal Treasury. Withdrawals are ruled by the Congressional appropriations process, which governs all public expenditures. In France, withdrawals from the individual waste generators' funds are made according to provisions of the contracts they established with ANDRA.[54] In Sweden, the payments are repaid to operators by SKI as and when they are required. Just as the payments are calculated and paid separately by each waste producer, the withdrawals from the funds are made separately.[55] By approving the annual budget of SKB, SKI determines the level of reimbursements from the fund.[56] In Germany, annual expenditures for exploration for disposal sites are budgeted and financed by the Federal government and then charged to the waste producers.[57]

Withdrawals are possible by producers in Finland if the assets in the fund exceed the currently estimated liabilities. Required fund contributions are spread over the life of each nuclear facility. The calculation of required contributions for the year ahead – or alternatively, fund surpluses – is done each December 31, and where there is a surplus, this amount is refunded to the waste producer by April 1. In addition, the licence-holders are entitled to borrow back 75 percent of the capital in the fund against full securities at the Bank of Finland based rate plus 2 percent, while the government is authorized to borrow the remaining 25 percent.[58]

5.3.3. Fund Auditing

In those countries where the funds have been established and the funds are contributed or withdrawn through national accounts, the organization responsible for auditing government finances also audits the financing system for long-term nuclear waste management (for example, the Financial Auditing Committee established by the Board of Directors of ONDRAF/NIRAS in Belgium).

In several countries, such as Switzerland and the U.S.[59], independent auditors are required to verify the proper management of the funds. In those countries where the funds are held in reserve by waste generators, the professional auditors under contract with the nuclear power plant operators serve this purpose.[60]

In Sweden, an independent government authority, the Board of the Nuclear Waste Fund, is responsible for ensuring that administration of the assets satisfies the requirements for a long-term adequate return and adequate liquidity. In addition, the fund is audited annually by independent and contracted accountants, as well as SKI, which usually orders extended audits.[61]

5.3.4. Investment and Risk Mitigation Strategy

The fund's goal is to ensure that resources are readily available to meet the liabilities as they arise. By definition, a fund set up to finance long-term management of nuclear waste would typically have a long-term horizon, which arguably makes it more suitable to the types of investments that can generate the highest rate of return over the longer term. On the other hand, a balance needs to be maintained to ensure sufficient liquidity to meet some of the near-term liabilities, as well as unexpected or prematurely occurring liabilities.

Assets in the fund can be invested in a variety of financial instruments. Financial instruments are subject to various financial risks, which the investment strategy needs to address. Among these risks are liquidity risk, market (systematic) risk, industry risk, currency risk, asset-class specific risks and security-specific risks.

Liquidity risk is the risk that funds may not be converted to cash at the desired time, within a desired price range, or in a desired quality or volume. The most liquid securities are typically cash and government-issued securities, while corporate bonds, equities and real estate are examples of less liquid investments. Liquidity risks can be mitigated by holding a portion of the funds in highly liquid securities, which is a common practice in countries that have set up such funds. For example, in the U.S., the annual surpluses are invested in treasury securities and potential shortfalls may be financed by borrowing from the Treasury.[62]

Another way to address liquidity risk is through maturity matching. For example, if a large portion of the waste management costs is expected to be incurred 30 years from now, then it is a good strategy to invest an adequate amount in assets with maturities of close to 30 years, to ensure cash inflows into the funds will be sufficient to meet the cash outflows necessitated by the planned expenditures. Maturity matching is an explicit part of the strategy of the Swedish Nuclear Waste Fund.[63]

Market risk is a type of risk, which is common to an entire class of assets. The value of assets may decline over a given time period simply because of economic changes or other events that impact parts of the market. Market risk can be avoided by investing in "risk-free" assets, such as short-term government securities and cash.

Since for liquidity reasons, a major portion of the funds are invested in interest-bearing securities, special attention needs to be given to the types of risk associated with this asset class, namely interest rate risk, credit risk, default risk, and inflation risk.

Interest rate risk is associated with potential changes in the value of interest-bearing securities, such as bonds, in response to changes in the market interest rates. Interest rate risk can be addressed by duration[64] matching strategies. For example, if the liabilities are discounted by current interest rates, then, all else being equal, the value of the liabilities will increase as market interest rates decrease. At the same time, a decrease in market rates will result in an increase in the value of the bonds that are held as assets in the portfolio. Thus, the resulting increase in the value of the assets could then be used to offset the increase in the liabilities.

Another common risk that is typically associated with interest-bearing securities is credit risk. Credit risk includes issuer risk and counterparty risk. Issuer risk is the risk that the issuer will not pay the interest and/or repay the principal. Issuer risk can be mitigated by investing in securities of issuers with good credit ratings, such as governments of developed, politically stable countries or high-grade corporate bonds (which is practised by most countries who have set up their funds). Another type of credit risk is counterparty risk, which is the risk that the counterparty to a financial transaction will not fulfill his/her obligations. This risk can be mitigated by setting up rules for executing transactions associated with the management of the fund's assets.

Inflation or purchasing power risk is the possibility that the value of assets or income will decrease as inflation erodes the purchasing power of a currency. Inflation risk can be addressed by investing a portion of the fund's assets in real-interest bearing securities. For example, in Sweden, a minimum of 60% of the capital in the fund must be invested in assets yielding a real return.[65]

If at least a portion of the costs is expected to be incurred in a currency other than the domestic currency, or a portion of the funds is invested in foreign-currency denominated securities, then currency risk would be present. Currency risk can be addressed by matching the foreign-currency denominated liabilities with the same-currency denominated assets. Alternatively, if the currency risk is present only on the asset side (i.e., a portion of the funds is invested in foreign-currency-denominated securities, while no portion of the costs is expected to be paid in the foreign currency), then currency hedging strategies can be employed, to neutralize the currency effect.

Another type of a potential risk is administrative risk, which is addressed by establishing auditing procedures and various internal and external controls ensuring the proper administration of the fund. This is achieved in many countries by having an independent body audit the fund's statements.

Finally, other types of risks, such as security-specific risks (unique to each type of security), asset-class specific risks (such as interest rate risk which is specific to fixed-income securities), and industry-specific risk (specific to the issuers within a specific industry) can be addressed through diversification.

In most countries, investment strategies employed by the managing organizations of the funds set up for long-term management of nuclear waste tend to trade a higher potential return for a more secure preservation of capital. Most countries hold a portion of their funds in cash, short-term investments, and government guaranteed bonds.

In several countries, more aggressive investment strategies have been employed. For example, in Switzerland, the funds are composed of both indexed and actively managed funds: the actively managed funds include portfolios of both Swiss franc- and other currency- denominated bonds and a combination of actively and passively managed domestic and international equities, plus a portion invested in real estate.[66] In Japan the funds are in government guaranteed bonds, local government bonds, and Yen-denominated corporate bonds (50% of the fund's assets are currently in national bonds).[67] In Spain, the funds are invested in fixed income portfolios with individual assets limited to those having first class financial ratings, including Spanish central and local government debt, highly rated foreign debt, debt of supranational organizations and high-grade corporate debt in the energy, transport, communications, and financial sectors (with the average historical return of the entire portfolio estimated at 3.5 percent).[68]

In other countries, the rules governing the investment strategies of these funds have evolved in the direction of greater diversification. In Sweden, legislation was passed in 2002 requiring investments with maturities exceeding one year to be invested in government bonds at market rates (as opposed to deposits in the National Debt Office). In addition, the Board of the Fund submitted a proposal to the government to allow the funds to be invested in financial markets, stating that "…with a limited higher risk, significantly greater expected return could be achieved if several types of assets and financial instruments were allowed." Following a formal review, the Board proposed in late 2001 that portfolio theory studies should be performed.[69]

Few countries have a target growth rate indicated for their funds. In Sweden, a specific target average annual return of at least 4 percent has been identified for the period of 1996 to 2020.[70] In Switzerland, individual goals are set for each nuclear power plant.[71]

There typically are provisions to prevent possible conflicts of interest. For example, in Switzerland, investments in companies associated with the contributors and those companies who have invested the majority of their assets in nuclear facilities are prohibited.[72] In Finland, supplementary securities provided as part of the contingency provision may not include mortgages on the nuclear power plants in question.

Appendix – Statutory and Regulatory Provisions

This section highlights the provisions of international conventions and Canadian legislation and regulations that pertain to economic and financial aspects of long-term management of high-level nuclear waste. (Note that no legal advice has been sought in the preparation of this section, that it should not in any way be construed as a legal opinion regarding the interpretation of any statute or regulation, and that it should not in any way be construed as a comprehensive list of all potentially relevant treaties, conventions, statutes, and regulations.)

The International Atomic Energy Agency *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* (the *Convention*) contains several clauses that are consistent with the "polluter pays" principle and the objective of not placing undue burdens on future generations.

Chapter 2, Article 4, clauses vi. and vii. state:[73]

> "Each Contracting Party shall take the appropriate steps to ensure that at all stages of spent fuel management, individuals, society and the environment are adequately protected against radiological hazards.
>
> In doing so, each Contracting Party shall take the appropriate steps to:
>
> > strive to avoid actions that impose reasonably predictable impacts on future generations greater than those permitted for the current generations;
> >
> > aim to avoid imposing undue burdens on future generations."

Chapter 4, Article 22, clauses ii. and iii. require that:

> "Each Contracting Party shall take the appropriate steps to ensure that:
>
> > adequate financial resources are available to support the safety of facilities for spent fuel and radioactive waste management during their operating lifetime and for decommissioning;

> financial provision is made which will enable the appropriate institutional controls and monitoring arrangements to be continued for the period deemed necessary following the closure of the disposal facility."

Turning to national statutes and regulations, a key document, of course, is the *Nuclear Fuel Waste Act*. Sections **9**. and **10**. establish the requirement for the nuclear energy corporations and AECL to maintain trust funds, as well as the required deposits (and interest that accumulates thereon) until a new funding formula is developed. Section **11**. lays out the provisions for the waste management organization to make withdrawals from the fund. It is interesting to note that this section gives the waste management organization authority to make withdrawals for both the purpose of implementing the selected waste management approach and for the purpose of "avoiding or minimizing significant socio-economic effects on a community's way of life or on its social, cultural or economic aspirations."

Section **12**. of the *Act* sets out the requirement to study, at a minimum, three waste management approaches, including "a comparison of the benefits, risks and costs of [each] 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" and "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."

Section **13**. contains a requirement that the aforementioned study set out a funding formula for each approach, including such terms as: the estimated total cost of management of nuclear fuel waste, including natural or other events that have a reasonable probability of occurring; the estimated rate of return on deposited funds; the life expectancy of nuclear reactors; and, the estimated amounts of waste to be received. The study also must address the breakdown of cost responsibilities across the nuclear energy corporations and AECL, and the form and amount of any financial guarantees that have been provided under the *Nuclear Safety and Control Act*. Section **16**. sets out requirements for reports, updates, and revisions related to the financial guarantees, cost estimates, and funding formulae. In the case where the total balance in the trust funds exceeds the estimated cost of implementing the selected waste management approach, or where the implementation of the approach has been completed, beneficiaries of the trust fund may be authorized by the Governor in Council to withdraw some or all of the balance in the trust fund under section **21**. Sections **22**. and **23**. impose requirements for record-keeping and independent auditing.

The *Nuclear Safety and Control Act* grants the Canadian Nuclear Safety Commission the authority to issue licences for nuclear facilities, including terms or conditions requiring that licensees provide financial guarantees (section **24**). *Regulatory Guide G-219: Decommissioning Planning for Licensed Activities* sets out guidelines to ensure that a life-cycle planning approach is taken in preparing decommissioning plans. Decommissioning plans must use “reasonably conservative cost estimates” and proposals for financial guarantee arrangements. *Regulatory Guide G-206: Financial Guarantees for the Decommissioning of Licensed Activities* states that estimates of the costs of implementing proposed decommissioning plans must include management or disposal of all wastes, including spent nuclear fuel, monitoring, and ongoing maintenance of any institutional controls. With regard to the management of high-level waste, the CNSC has asked licensees to supply cost estimates assuming the most expensive of the options under consideration by the NWMO.[74] The CNSC also notes in *Regulatory Guide G-206* that “Financial guarantees must be sufficient to cover the cost of decommissioning work resulting from licensed activities that have taken place prior to the licence period, or will take place under the current licence.” This document sets out standards for costing and cost contingency requirements. It also notes that financial guarantees must be at arm’s length from the licensee and accessible by the CNSC upon demand. Examples of financial guarantees acceptable to the CNSC include cash, irrevocable letters of credit, surety bonds, insurance, and expressed commitments from a government. The general criteria for acceptability are liquidity, certainty of value, adequacy of value, and continuity.

In regard to the “polluter pays” principle, the CNSC’s *Draft Regulatory Policy P-290: Managing Radioactive Waste* states the following as a key policy principle: “The establishment of arrangements to fund any measures needed to protect the environment and persons from the radioactive waste, and the implementation of such measures, should not be deferred unduly so as to impose a burden on future generations.”

The CNSC also has issued a policy regarding the use of cost-benefit information (*Regulatory Policy P-242: Considering Cost-benefit Information*) that states:

> “It is therefore the policy of the Commission that:
>
> - When conducting a proceeding for purposes of a decision under the *Nuclear Safety and Control Act* that involves a licence or an order, the Commission or its designated officers will consider relevant information on costs or benefits that is submitted by a person who is participating in the process.

- When conducting consultations on a draft regulatory standard or a draft regulatory policy, the Commission will take into account, when fixing the deadline for submission of comments, the time that may be required for the preparation of submission on the costs and benefits related to the proposed standard or policy.

- When receiving or considering any relevant information on costs or benefits that is submitted in relation to a decision involving a licence or order, the Commission or its designated officers will be governed by the following principles:

  - Information on costs and benefits is only one factor that may be considered in making 'regulatory decisions' or taking 'regulatory actions' under the Act, and does not displace legal requirements and other valid regulatory considerations.

  - The information on costs or benefits may be quantitative or qualitative in nature.

  - Consideration of the information on costs or benefits may be quantitative or qualitative in nature.

A final set of relevant statutory and regulatory provisions are those enforced by the Canadian Environmental Assessment Agency.

Section **16**. of the *Canadian Environmental Assessment Act* requires that "comprehensive studies" include a review of a project's environmental effects (where environmental effects are defined to include effects on socio-economic conditions), measures that are technically and economically feasible and that would mitigate any significant adverse environmental factors of the project, and alternative means of carrying out the project that are technically and economically feasible and the environmental effects of any such alternative means.

The *Comprehensive Study List Regulations* specifically cites, in Schedule 3, Part VI, the construction, decommissioning or abandonment of nuclear fuel storage and disposal facilities as projects that require a comprehensive study (as opposed to other less intensive types of reviews that the CEAA may undertake).

(We do not specifically address provincial statutes and regulations in this paper, but we do note that some provinces have concluded formal arrangements with the federal government regarding joint environmental assessments, and that other provinces commonly pursue similar arrangements on a less formal level.)

To summarize, the statutory and regulatory provisions discussed above:

- are consistent with the "polluter pays" principle and the objective ensuring that future generations do not face undue cost burdens;
- require comparative assessments of benefits, costs, risks and other economic effects cross alternative approaches;
- set out measures to ensure the adequacy, integrity, and sustainability of funding mechanisms established to cover future cost liabilities.

Notes

[1] Section **12.** (2) of the *Nuclear Fuel Waste Act* directs the NWMO to examine, at a minimum, three waste management approaches: deep geological disposal in the Canadian Shield; storage at nuclear reactor sites; and centralized storage, either above or below ground. Throughout this paper we refer to the long-term "management" of waste as being an umbrella concept encompassing both "storage" – which implies there is a provision for retrieval, and "disposal" – where placement is permanent with no intention of retrieval.
[2] Note that in a benefit-cost analysis, such "avoided costs" would be classified on the "benefit" side of the ledger.
[3] The October 2003 report "Status of Financing Systems for High-Level Radioactive Waste Management (HLRMW)" prepared for the NWMO by GF Energy, LLC notes that all of the countries it has surveyed have endorsed the "polluter-pays" principle.
[4] The mandate of the NWMO is focused on the long-term management of high-level nuclear waste. Other issues such as the management of low-level waste and the decommissioning of reactor sites are important matters, but these are beyond the scope of this paper.
[5] "The Disposal of Canada's Nuclear Fuel Waste: Engineering for a Disposal Facility," G.R. Simmons and P. Baumgartner, AECL Research, 1994.
[6] Present value versus current value costing approaches are discussed further in section 5.
[7] For example, CIBC Mellon Trust Company manages the funds of OPG and NB Power.
[8] NEA, pp. 10-11.
[9] "Financing: Covering the expenses for nuclear waste,"SKI brochure, p.7.
[10] NEA, p. 56.
[11] "Kingdom of Belgium, National Report, First meeting of the Contracting Parties to the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management," November 2003, p. 44.
[12] NEA, p. 64.
[13] IAEA, p. 80.
[14] NEA, p. 15.
[15] NEA, p.15.
[16] Under the conditions of the proposed restructuring of British Energy, the already-existing Nuclear Decommissioning Fund (NDF) would be enlarged into the Nuclear Liabilities Fund (NLF), to cover previously uncontracted-for decommissioning and waste management costs. Based on British Energy PLC Announcement of Formal Agreement on Proposed Restructuring, October 1, 2003, p. 15.
[17] GF Energy background doc, p. 9.
[18] EC, p. 75.
[19] Morsleben repository was inherited from East Germany upon unification.
[20] "Kingdom of Belgium, National Report, First meeting of the Contracting Parties to the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management," November 2003, p. 45.
[21] EC, p. 12.
[22] NEA, p. 56.
[23] NEA, p. 64.
[24] EC, p.33.

[25] IAEA, p. 64.
[26] IAEA, p. 64.
[27] NEA, pp. 59-61.
[28] NEA, pp. 59-61.
[29] IAEA, p. 58.
[30] British Energy PLC Announcement of Formal Agreement on Proposed Restructuring, October 1, 2003, p. 32..
[31] Standard contract 10 CR 961, as presented in GF Energy's Background Paper, p. 22.
[32] There is also the risk that either the size of the liabilities will prove to be overestimated, or the liabilities come due later than expected. These risks also need to be considered, but are less critical.
[33] EC, p. 76.
[34] IAEA, p. 81.
[35] IAEA, p. 133.
[36] This example is based on the experience of Nirex in the UK. Based on EC, p. 60.
[37] EC, p. 55.
[38] "SAFIR 2: Safety Assessment and Feasibility Interim Report 2," ONDRAF/NIRAS (Belgian agency for radioactive waste and enriched fissile material), NIROND 2001-06 E, December 2001.
[39] "Schemes for Financing Radioactive Waste Storage and Disposal," European Commission, 1999, pp. 11-12; plus follow-up communication with ONDRAF/NIRAS.
[40] NEA, p. 15.
[41] NEA, p. 37.
[42] NEA, p. 64.
[43] GF Energy, p. 45.
[44] "Financing: covering the expenses for nuclear waste," SKI brochure, p.10.
[45] "Institutional framework for long term management of high level waste and/or spent nuclear fuel," International Atomic Energy Agency (IAEA), December 2002, p. 25.
[46] There are some limitations to the types of acceptable securities: mortgages on the power plants are not acceptable. Based on NEA, p. 57, as well as EC, p. 24.
[47] In addition to nuclear waste management, the funds may cover other activities, such as decommissioning or R&D.
[48] EC p. 76.
[49] Ministry of Industry oversees operations of waste producers.
[50] Prior to July 2001, this responsibility was with the Ministry of Economic Affairs, who commissioned independent organizations to estimate waste management costs, which were the basis for payments by utilities. As of April 2002, the utilities have bought off all current obligations and future liabilities concurrently with the transfer of their shares in COVRA to the state. Based on IAEA, p. 96.
[51] The Ministry of Finance and COVRA are in the process of setting up an auditing system to be used after the transfer of the shares to the government.
[52] Compagnie Générale des Matières Nucléaires, subisidary for CEA's certain industrial activities.
[53] "Liabilities identification and long-term management at national level," Topical Session held during the 36th Meeting of the Radioactive Waste Management Committee, Nuclear Energy Agency, March 13, 2003, France, NEA/RWM(2003)14, October 7, 2003, pp. 12, 16-17.
[54] IAEA, p. 58.
[55] EC, p. 53.

[56] NEA, p. 24.
[57] IAEA, p. 65.
[58] EC, p. 24.
[59] In the U.S., KPMG Peat Marwick LLP conducts independent annual audits of the Nuclear Waste Fund. Based on IAEA, p. 154
[60] "Institutional framework for long term management of high level waste and/or spent nuclear fuel," International Atomic Energy Agency (IAEA), December 2002, p. 14.
[61] IAEA, p. 133.
[62] IAEA, p. 154.
[63] "Annual Report 2002," Kärnavfallsfonens Styrelse, The Board of the Swedish Nuclear Waste Fund, 2002, p.9.
[64] Duration measures the average time to maturity of a fixed-income portfolio and approximately equals the unit change in the market value of a portfolio in response to a unit parallel shift in the market yield curve.
[65] Annual Report 2002, the Board of the Swedish Nuclear Waste Fund, p.9.
[66] NEA, p. 17.
[67] "Status of Financing Systems for High-Level Radioactive Waste Management (HLRWM), GF Energy, LLC, NWMO Background paper, p. 46.
[68] EC, p. 46.
[69] "Annual Report," Karnavfallsfonens Styrelse, The Board of the Swedish Nuclear Waste Fund, 2002, p.6.
[70] This rate is based on the historically achieved rate of return on the fund's assets."Annual Report," Karnavfallsfonens Styrelse, The Board of the Swedish Nuclear Waste Fund, 2002, p.4.
[7171] NEA, p. 17.
[72] "Liabilities identification and long-term management at national level," Topical Session held during the 36th Meeting of the Radioactive Waste Management Committee, Nuclear Energy Agency, March 13, 2003, France, NEA/RWM(2003)14, October 7, 2003, p. 12.
[73] Similar language appears in Chapter 3, Article 11, clauses vi. and vii. with regard to radioactive waste, as opposed to spent fuel.
[74] As noted, for example, in "Information and Recommendations of Canadian Nuclear Safety Commission Staff – In the Matter of Ontario Power Generation Inc./Bruce Power Inc.," April 10, 2003.