nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

November 2003

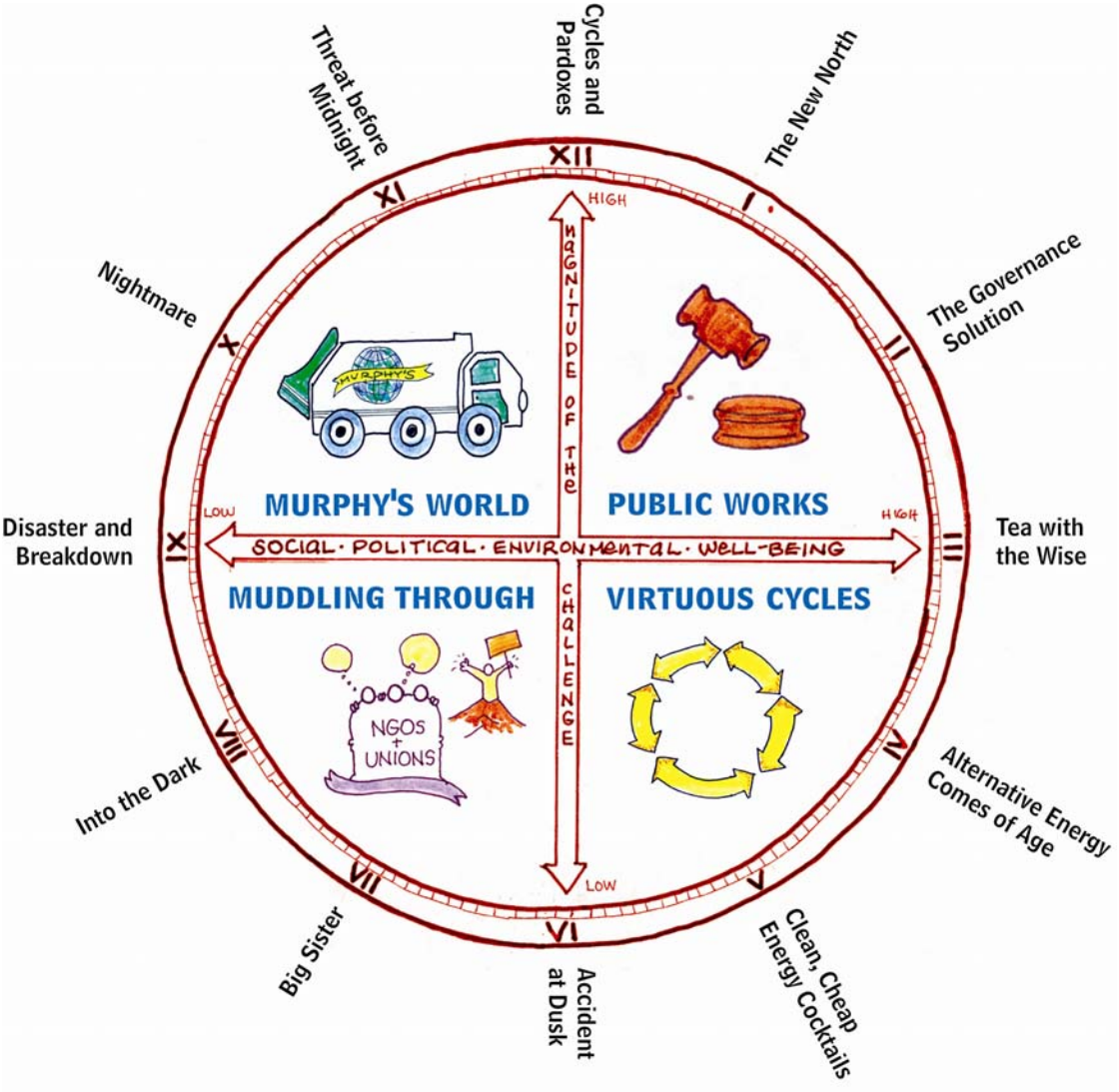
NWMO BACKGROUND PAPERS
8. WORKSHOP REPORTS

8-5 LOOKING FORWARD TO LEARN: FUTURE SCENARIOS FOR TESTING DIFFERENT APPROACHES TO MANAGING USED NUCLEAR FUEL IN CANADA

GBN, Global Business Network

Looking Forward to Learn:

Future Scenarios for Testing Different Approaches to Managing Used Nuclear Fuel in Canada



Submitted by
Global Business Network
to the
Nuclear Waste Management Organization

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GBN Global Business Network

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Preface

In November 2002, the Government of Canada enacted the *Nuclear Fuel Waste Act*. The purpose of the Act is to provide a framework that will enable the Governor in Council (the federal cabinet), on the advice of the Minister of Natural Resources, to make a decision on how Canada will move forward with management of used nuclear fuel. To proceed, the Act requires the nuclear energy corporations who produced the waste to create and fully fund a not-for-profit corporation, the Nuclear Waste Management Organization (NWMO), that will:

1. Undertake a study of alternative management approaches encompassing the needed research and collaborative deliberation with Canadians;
2. Provide a recommended management approach in a report to the Minister by November 15, 2005; and
3. When the Cabinet has made its decision on how to proceed, become the implementing agency for long-term management of used nuclear fuel in this country.

In the early Spring 2003, the NWMO initiated its program, the details of which are summarized in its first major discussion document, *Asking the Right Questions?,* which is available online at http://www.nwmo.ca . Key components of this program include:

1. The initiation of a comprehensive engagement program to ensure that the recommended management approach is built through the collaborative effort of a broad range of Canadians and as a result, reflects their values;
2. The commissioning of a series of papers and the convening of a number of workshops to address a range of perspectives, knowledge areas, fundamental concepts and underlying issues;
3. Development of an analytical framework based on all of the above and its application in an open and collaborative process for assessing the various management approaches

A key challenge for the NWMO is to bring to its work knowledge about what future conditions might be like. The motivation is simple: NWMO needs to prepare as best it can for any eventuality. The Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel (the Seaborn Panel) fully understood this need and in their 1998 report recommended that follow-up efforts should include scenarios work.

For the NWMO, considering various futures helps to identify the range of conditions that may have to be faced in managing used nuclear fuel over the long term. Doing so strengthens understanding of the characteristics that need to be built into the management approach chosen for implementation. In turn, this same understanding will help identify which of the alternative management approaches will be best able to respond to future conditions while achieving a fair and acceptable distribution of costs, benefits, and risks across today's society as well as across future generations.

To undertake this element of work, NWMO turned to Global Business Network (GBN) based in Emeryville, California. GBN was founded in 1987, gathering the leading practitioners from Royal Dutch/Shell and Stanford Research Institute (SRI) International—the two institutions which developed scenario planning over the previous two decades. Its founders are not only leading practitioners of the scenario method but, together with their dozens of network members, have considerable expertise in addressing the kind of multi-faceted social/technical issue that is presented by long-term management of spent nuclear fuel.

To work with GBN, the NWMO convened a Scenarios Team of 26 individuals from a range of interests and locations across Canada. They are listed below along with the GBN Facilitating Team and GBN network members who were brought into the process in a supportive role.

Selection of the team followed an iterative process of (1) identifying communities of interest important to the NWMO's work; (2) seeking advice from within each community of interest as to who might be both interested in contributing and available to give the required time commitment (four workshops plus review over a 6 month period); (3) following leads to potential members and inviting participation, keeping in mind not only the original concept of communities of interest but also geographic, gender, and age distribution. A special effort was made to involve First Nations people.

Though initially approached because of the particular interest they might bring to the table, participants were explicitly freed from any obligation to represent any organization or interest. Rather, they were asked simply to offer their personal perspectives. In turn, the NWMO made it clear that their participation did not in any way imply agreement with the mandate or recommendations of the NWMO. This condition was formally entrenched in a set of "Principles of Participation" that governed the process. These principles, shown below, were reviewed and agreed to at the beginning of the exercise by all participants.

I would like to thank Liz Dowdeswell and the staff at NWMO for choosing GBN to lead the scenario development process, and Tony Hodge for his support throughout the process. Credit goes to all of the team members for providing the creativity and content in the following report. The scenario development process is highly interactive and relies on the team members for its quality. Once their ideas were solicited, however, it fell to me to weave them together into the following narratives, and I take full responsibility for any errors of inflection or nuance that may remain even after several cycles of iteration and review.

Jay Ogilvy
Cofounder of GBN

NWMO Scenarios Team, Principles of Participation

Below are listed ten assertions that provided the basis for participation in the NWMO Scenarios Exercise.

Our intent is:

1. To explore, not negotiate;
2. To share, not to decide;
3. To inform and when requested, to advise;
4. To understand the diversity of perspectives and build relationships;
5. To consider how to widen the network of connections with which NWMO will need to build complementarity and linkages;
6. To help guide the flow of the discussions in such a way that areas of common ground and of differences are identified along with the underlying reasons; and
7. To respect that participation and contributions are not to be seen as an endorsement by any participant of the NWMO project (or any specific outcome of it).

Attribution of comments:

8. No specific attribution of any comment made by any participant(s) will be referenced in any notes unless specifically requested by the participant(s).

Notes

9. Notes will be prepared from the activity (meeting, workshop) and shared, either with a representative group if identified at the activity or the full group prior to finalization. Notes shall typically be of a summary nature and will include a list of participants.
10. Any notes prepared should include at the beginning, this "Basis for Participation" which shall have been discussed with participants at the beginning of the activity.

Source: Glenn Sigurdson, CSE Group
Vancouver, B.C. Canada

Participants in the NWMO Scenarios Exercise

1. Suzie Basile (substitute for Lynn Katsitsaronkwas Jacobs, Workshop 4) First Nation Sustainable Development Institute, Assembly of First Nation of Quebec and Labrador, Quebec City QC
2. Robert Boisvert, Vice President, Canadian Nuclear Workers Council, Trois-Rivières, QC
3. Nicole Boyer (GBN Facilitating Team), Paris
4. Stewart Brand (GBN Network Participant)
5. Doug Bruchet, Senior Vice President Environment, Canadian Energy Research Institute, Calgary, AB
6. Lynn Carruthers (GBN Facilitating Team)
7. Denise Caruso (GBN Network Participant)
8. George Connell, Retired, former President, University of Toronto, Vice-president, Lake Simcoe Region Conservation Foundation, Toronto, ON
9. Ann Coxworth, Saskatchewan Environmental Society, Saskatoon, SK
10. Abdallah Daar, Professor of Public Health and Surgery and Director of the Program in Applied Ethics and Biotechnology, University of Toronto, Toronto, ON
11. Tina Estes (GBN Facilitating Team)
12. Jo-Ann Facella (NWMO)
13. Al Freeze, Consulting Hydrogeologist (retired) and author, White Rock BC
14. Jerry Grandey, President and CEO, CAMECO Corporation, Saskatoon, SK
15. Mary Lou Harley, United Church of Canada, Port Williams, NS
16. Tony Hodge (NWMO)
17. Lawrence Ignace, Manager, Environmental Secretariat, Assembly of First Nations, Ottawa, ON
18. Lynn Katsitsaronkwas Jacobs, First Nation Sustainable Development Institute, Assembly of First Nation of Quebec and Labrador, Kahnawake Mohawk Territory, QC
19. Rick Jennings, Director, Energy Policy, Ontario Ministry of Energy, Toronto, ON
20. George Lafond, Special Advisor on Aboriginal Initiatives, Office of the President, University of Saskatchewan, Saskatoon, SK
21. Colin Macdonald (substitute for Jerry Grandey, Workshop 1), CAMECO Corporation, Saskatoon, SK
22. Ken McCready, Energy Council of Canada, K.F. McCready and Associate Ltd., Calgary, AB
23. Bernard Michel, Chairman of the Board, Bruce Power Inc., ON
24. Irving Mintzer (GBN Network Participant)
25. Jay Ogilvy (GBN Project Leader)
26. Philip Raphals, Director, Helios Centre, Montreal, QC
27. Marlo Raynolds, Director, Ecosolutions, Pembina Institute for Alternative Technology, Calgary, AB
28. Andrew Roman, Miller Thomson, Toronto, ON
29. Fred Roots, Senior Advisor Emeritus, Environment Canada, Sooke, BC
30. Norm Rubin, Senior Consultant, Borealis Energy Research Association; Director of Nuclear Research and Senior Policy Analyst, Energy Probe, Toronto, ON
31. Rusty Schweickart (GBN Network Participant)
32. Barry Stuart, Judge, retired, CSE Group, Vancouver, BC
33. Scott Vaughan, Visiting Scholar, Carnegie Endowment for International Peace Washington, DC

I Introduction

Canada's Nuclear Waste Management Organization (NWMO) was created at the end of 2002 and asked as an initial task to study and make a recommendation to the Government of Canada on a preferred approach to managing used nuclear fuel in Canada over the long term. In response and from its inception, the NWMO has committed to "develop collaboratively with Canadians a management approach for the long-term care of used nuclear fuel that is socially acceptable, technically sound, environmentally responsible, and economically feasible."[1]

For the NWMO, the concept of a "management approach" is broad and includes not only the technical method or sequence of methods to be used (the built facility wherever it is located), but also the related infrastructure and support systems (including transportation); the legal, administrative, and financial arrangements; details of the implementing organization; and a full implementation strategy.

As part of its work and responding in part to the 1998 recommendations of the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel (the Seaborn Panel) the NWMO initiated a formal scenarios exercise early in its program of activities.

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

In the exercise documented by this report, various futures were considered in order to develop a sense of what kind of conditions might have to be faced in managing used nuclear fuel over the long term. Although we cannot know what future societies *will* look like, we can try to anticipate what they *may* look like by envisioning a broad range of possibilities. This is the approach taken by formal scenarios technique. Using the insight of a team of individuals drawn from many interests, a range of futures is designed, each of which is plausible (some more so than others, perhaps) according to what we know today. Some of these futures may be more desirable than others but in this effort, we are neither setting out to design a future that we want, nor to predict the future we expect.

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

Under the facilitation of the Global Business Network (GBN), the NWMO Scenarios Team set out to:

- Design a series of scenarios that would span a wide range of alternative plausible futures;
- Draw criteria from that work that should be used for analyzing alternative management approaches;
- By doing this, strengthen our preparedness for whatever future unfolds;
- Contribute to understanding the differences in perspectives held by various communities of interest reflected in the Team's composition, while building confidence in the NWMO process of analyzing alternative management approaches; and
- Do so giving consideration to four time horizons: 25 years (1 generation); 175 years (7 generations): 500 years (20 generations) and 10,000 years (400 generations).

[1] NWMO Mission Statement, on-line at www.nwmo.ca.

Scenarios are stories with beginnings, middles, and ends. While it is possible to build such logic with some confidence using a 25 year time frame and with much less confidence using a 175 year time frame, moving beyond is nigh impossible: there are just too many options and too much that is unknown. As a result, deliberations at the 500-year time horizon led to descriptions of what came to be known as "end-points" or short descriptions of sets of conditions but with no attempt to structure a logical story. Furthermore, at 10,000 years, the best that the Team could do with any degree of comfort was to generate a series of short statements describing, "what-if such-and-so might happen?"

The full assembly of future possibilities then took the form of four fairly detailed stories extending out 25 years (Part IV); 12 much briefer scenarios reaching out 175 years (Part V); 16 End-points at 500 years (Part VI), and a long list of very brief What-ifs for 10,000 years (Part VII). This distribution of shorter and longer lists of, respectively, longer and shorter descriptions satisfies the requirement that we say with relative precision and confidence what we can about the relatively short term, and to outline very briefly as many possibilities as we can imagine in the very long term.

Throughout the development of these various perspectives on how the future might unfold, conditions were highlighted that would influence today's decision that Canada faces about the choice and design of a management approach for used nuclear fuel. These conditions were then captured in questions to be asked of each alternative management approach (Part VIII). In a final exercise, the process was inverted and four management approaches, crudely drawn together, were used to test the effectiveness of the various scenarios.

All of the insights generated throughout are summarized in a set of final observations and recommendations (Part IX).

II. What are scenarios . . . and what are they *not?*

Scenarios are descriptions of alternative environments in which today's decisions may be played out. They are not predictions. Nor are they strategies. Instead they are descriptions of different futures specifically designed to highlight the risks and opportunities involved in specific strategic choices.

Scenarios can help overcome anxiety about the lack of evidence regarding the future, for scenarios do not claim to be predictions. The point is not to gather evidence for some induction about a most probable future. The point is rather to entertain a number of different possibilities in order to make better choices in the present.

We cannot know what the future will hold beforehand. So-called futurists cannot be seers. But we can see in the present several trends which, moving on their current course, could change the shape of Canada, the world, and the nuclear industry for generations to come.

It's important to appreciate the *fictional* nature of scenarios. They are stories, not forecasts. As such, they call for the kind of narrative details that tell a tale colorfully. But the plausibility of a scenario does not hinge on the occurrence of any particular detail. In the first scenario below, for example, Bruce Power is shut down. Naming a particular generating facility makes for a better story, but the story could unfold just as well if Bruce kept operating and another power station were shut down instead. While reading scenarios, consider names, dates and other particular details as placeholders for *types* of events, not as necessary conditions for any particular scenario to unfold.

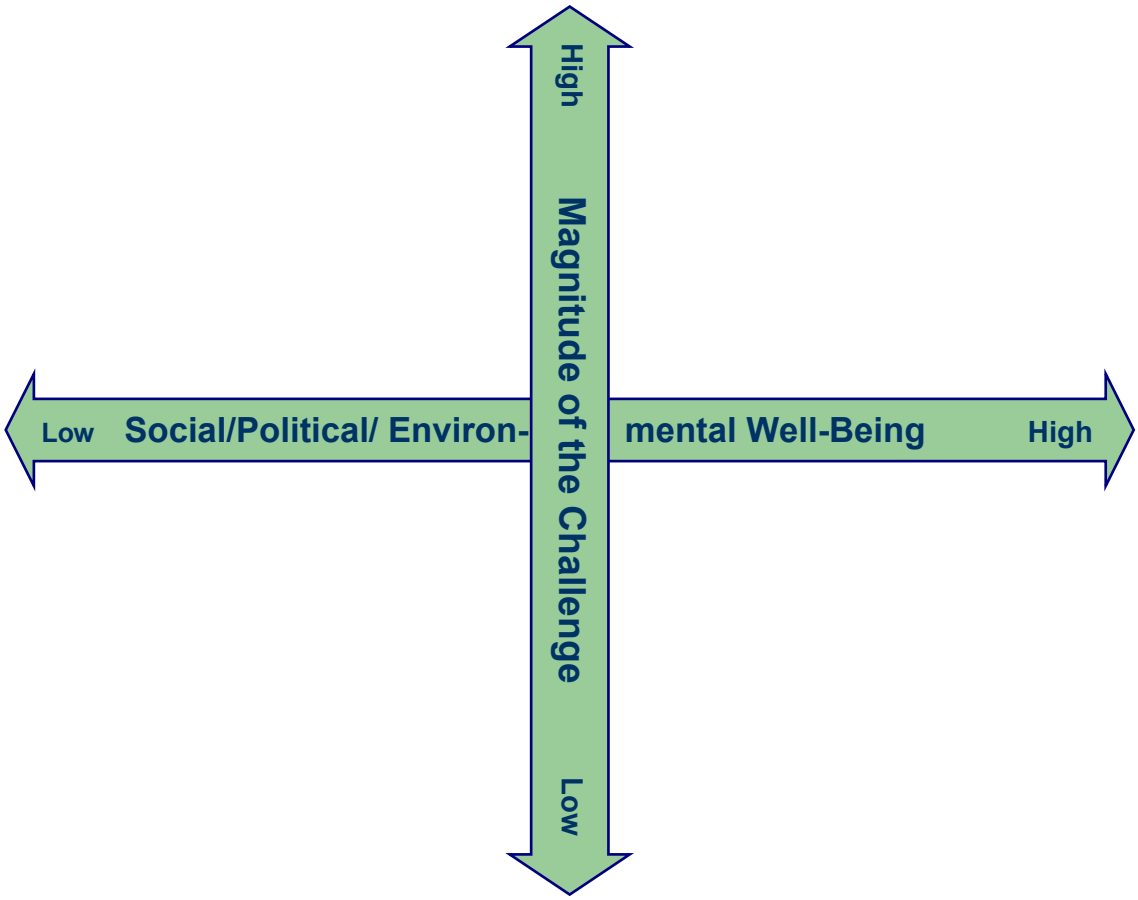
III. How were the scenarios developed?

Once we acknowledge that the future is not predictable, then a virtually infinite number of possible scenarios invite attention. Why settle on any particular plots to develop in detail?

The NWMO scenario team followed a method developed and tested over several decades. The exercise commenced with a discussion to confirm the focal issue:

> What criteria should be applied in Canada for deciding how to manage used nuclear fuel?

After brainstorming a list of no less than 180 different factors that could influence the outcome of different options for the management of spent fuels, each member of the team was asked to evaluate items on the list according to (a) their relative importance to the outcome, and (b) their degree of uncertainty. After collating the independent judgments of everyone on the team, and clustering closely related items, the group identified two critical uncertainties to serve as the axes of a 2X2 scenario matrix:



Explanation of the Two Axes

These two axes—"Magnitude of the Challenge," and "Social/Political/Environmental Well-being," contain a number of different uncertainties, and so much the better. Given that a 2X2 matrix must compress a very complex n-dimensional space onto a two-dimensional plane, it is important that each of the axes be capable of representing as much information as possible.

So, for example, there are several different forces that could push the future up or down the vertical axis, increasing or decreasing the "challenge":

- The quantity of spent fuel to be managed
- Energy demand, which, to the extent that the nuclear industry remains active, might lead to more or less spent fuel
- Economic vitality, which might drive energy demand
- The availability (or not) of technologies for storage and/or transmutation of nuclear wastes.

Likewise, a number of different forces or events could push the future to the right or to the left along our horizontal axis:

- Public trust in corporations
- Respect for government—"governability" (think of Russia, or Rwanda)
- War or peace
- The effectiveness of international and trans-national institutions
- The health of the natural environment

Neither of these short lists of bullet points claims to be complete. But they do illustrate the complexity of the uncertainties represented by the two axes.

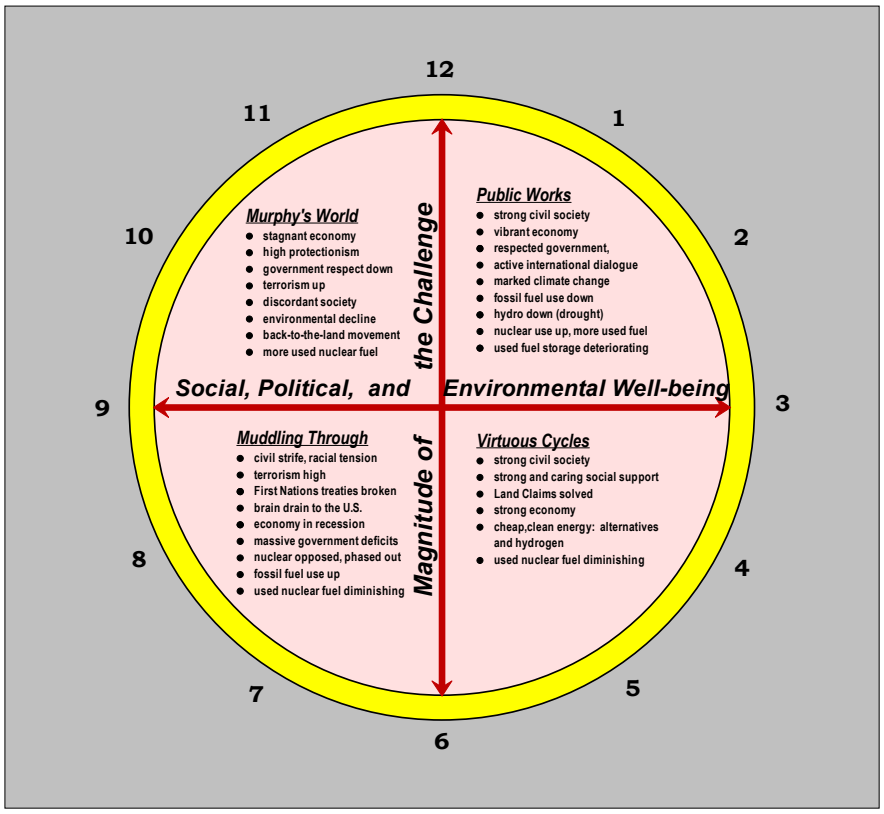
NWMO's ultimate client for this work, Parliament, is a legislature first and foremost. Its product is laws. The generic legal institutions we have in place are likely to be insufficient to provide an adequately robust legal foundation for the long-term management of nuclear waste. Therefore the more variability we can imagine in our scenarios, the greater the need to consider the legal underpinnings for any management program, including the legal underpinnings of various potential regulatory regimes.

Granting the complexity and/or ambiguity of our two axes of uncertainty, they nonetheless serve to guarantee that the scenarios in the four quadrants of the matrix will differ from one another in ways that make a difference. Why? Because they are based on the considered judgments of the members of the scenario team, who were asked to prioritize key factors according to the criteria of *importance* AND *uncertainty*.

Items judged certain—predetermined elements—may also be judged important, but just because they are predetermined, they are bound to show up in all scenarios. By identifying the two most critical *un*certainties, we guarantee that our scenarios will differ from one another by virtue of their uncertainty, and that they will differ in ways that have been judged *important* or *critical* to the focal question.

Many different futures can be imagined. Using a scenario matrix like the one just described allows us to be confident that the scenarios will address the issues deemed most significant.

IV. 25-year Scenarios



Upper-Right Quadrant – *Public Works*

- **High magnitude of challenge**
- **High degree of social, political, and environmental well-being**

75 years ago, at the dawn of the age of nuclear energy, it was generally thought that the eventual disposal of nuclear wastes was a relatively minor problem that would be solved in fairly short order. Back then we didn't worry that much about *any* kind of wastes—solid, toxic, or industrial. Rachel Carson had just begun working on *Silent Spring.* Nobody was thinking about *Limits to Growth.* While Canada was far less committed to the throw away, disposable society than her neighbor to the south, the very idea of recycling was unfamiliar to many.

How things change! During the last decades of the last century, the environmental movement kicked into high gear. Parents learned about recycling from children who came home from school filled with tales of all the good that could be done if we separated our trash into paper, plastics, cans and bottles. But no one had any stories to tell about the long-term management of nuclear wastes. In nation after nation around the world, scientists and policy makers proposed concepts to

deal with the problem of spent fuel . . . but no one came up with an answer that was satisfactory to critics.

Canada's nuclear industry took some pride in its innovative CANDU reactors. But Canada was no more successful than other nations at figuring out how to manage spent fuel. And Canada, despite its rich endowment of hydro power, and hydrocarbons, had an energy problem: A growing economy and long winters spelled increasing demands for energy, while growing sensitivity to the quality of the environment put increasing pressure to stop the burning of hydrocarbons.

Global warming may have sounded at first like a good thing to Canadians shivering through long winters. But when the West Antarctic Ice Sheet started sliding toward the sea and breaking off into huge icebergs, environmentalists called for sharp reductions in the burning of coal, oil and natural gas. Nuclear seemed to be the obvious replacement.

Not that other alternatives hadn't been tried. The hydro boom of the mid 00's had developed the remaining economically feasible large sites, with most of the power going to the US. Now that Canada's supply/demand balance was heading into the red, the full impact of NAFTA's restrictions on export reductions — whereby Canada could not unilaterally reduce its exports in any year lower than the average level of the three preceding years, even if it needed the power domestically — kicked in. Canadians were gradually coming to grips with the fact that they couldn't simply "repatriate" these power exports for their own needs. Meanwhile the federal government, flush with five years of economic success, projected increasing energy shortages by 2010, and advocated support for wind, solar, and biomass energy programs. But it soon became clear that developing renewable fuels in the needed quantities would cost far more than traditional fuels, and British Winds threatened to withdraw from Canada if it failed to receive a massive handout from a government riding high on rising tax revenues.

British Winds stood in line behind others who had come to expect a lot from politicians. After all, hadn't Ottawa shown gumption in closing down the Bruce Power Station until a new technology to minimize quantity and the bio-hazard of the waste was in place? Weren't they acting responsibly in increasing spending on nuclear waste regulation? Hadn't they approved vast sums for nuclear waste management?

Governments throughout the world gained greater power and respect during the first decade of the new millennium. Following the fall of communism and frequent calls for deregulation and the privatization of everything, the tide turned at the dawn of the 21st century. Corporate scandals, 9/11, and an increasing recognition of global problems that markets could not solve led to a sometimes grudging recognition that the public sector had important jobs to do, not the least of which would be the regulation of energy production and the management of growing supplies of nuclear waste. But just because government enjoyed a level of legitimacy that had been declining in earlier decades, that didn't mean that those in government had technically satisfying answers for how to deal with mounting quantities of spent fuels.

Canada adopted the world's strictest environmental standards. By 2025 Canada's last coal-fired plant was shut down. With no expansion in the exploitation of oil sands, energy costs were escalating across the board. After Canada and US agreed on standards for dealing with increasing amounts of spent fuel, the Canadian government announced a major increase in the development of nuclear energy. Expecting civil disobedience at the announcement, the police were well prepared for demonstrations, but true to a long Canadian tradition of respect for public institutions, those demonstrations remained peaceful. The politicians were just doing their jobs. Hard choices had to be made and someone had to make them.

The Prime Minister hailed a new era of global cooperation in addressing the global warming issue after the US dropped its long-standing opposition to a UN governance agreement. While GFD (General Ford Daimler) fought new taxes levied on gasoline-powered cars, the citizenry was

clearly in support of the measure. The EU also implemented a massive carbon tax, in a tardy attempt to stem global warming.

The funds set aside for nuclear waste management as of 2018 were deemed insufficient in 2019 so the government allocated an additional $15 billion to the still unsolved problem. Canisters containing nuclear wastes first stored decades earlier were showing signs of corrosion, and still no new technology to reduce the problems associated with nuclear wastes had been found.

With no end to the northern drought in sight, hydro generation in 2020 was the lowest since 1998. So despite the lack of a long-term solution to the management of nuclear wastes, the Canadian government authorized construction of a new generation of "safe nukes." By 2028, nuclear energy was supplying 10% of the energy mix in Canada.

After developing the scenarios, the scenario team brainstormed lists of early indicators that would allow advance warning that one or another scenario was about to unfold. These lists make no claim to being complete or definitive, but they offer a sense of the sorts of things one could look for to provide early warning of one or another scenario. Some of the early indicators take the form of trends that can be tracked, others are more episodic or anecdotal; some can be monitored on a monthly or yearly basis; others are one-off warning signs; some point toward a given scenario, others away. Some of the indicators were provoked by consideration of longer-term scenarios, but we have grouped all of them here following the 25-year scenarios because the readers of this report will look for these indicators during the coming decades.

Early indicators:

- Trend away from anti-nuclear among environmentalists
- Level of government funding for alternative fuels frozen
- Tax reform shifting mix of energy technologies and fuels toward nuclear
- End of perverse subsidies favoring hydrocarbons
- Increased wages and outreach to experts by government
- Increased number of slots in universities offering nuclear energy degrees
- Initial increase, followed by a decrease in number of decentralized sources of energy
- Drought, level of fresh water reserves
- Unit costs of wind-power dropping only slowly
- Adoption and enforcement of Canadian environmental standards
- Continued ineffectiveness of waste programs in other countries
- Literature and the arts, editorials, movies like 'China Syndrome'
- Indications of a breach in containment

Lower-Right Quadrant -- *Virtuous Cycles*

- **Low magnitude of challenge**
- **High degree of social, political, and environmental well-being**

When technical solutions serve social harmony, and social inventions support technical breakthroughs, a virtuous circle can improve the standard of living for all. Once you have both chickens and eggs, it's hard to imagine just how the cycle got started. But once a virtuous cycle has been set in motion, its self-supporting circularity is salient.

Which came first? Certainly the volunteer surrender of several Al Qaeda leaders to Dutch peacekeepers allowed the entire world to breathe a sigh of collective relief, especially when they called for a reduction in violence on the part of their followers. "Let us bring an end to the deaths of innocents," they said. "Let Allah shower rewards on his people," by which they may have been calling for an economically rewarding reconciliation between Islam and the rest of the world.

In Canada, the mood of reconciliation took the form of new initiatives toward Aboriginal peoples. Taking a leaf from Nelson Mandela and Bishop Desmond Tutu in South Africa, Canada sponsored a series of healing circles to bring to light shameful misdeeds in Canada's past, and then a series of moving rituals to lay them to rest. Was there a relationship between those rituals and some of the tribes' new openness to energy development? Some tribes were understandably reluctant to engage in the rituals of reconciliation. Some objected to what they called "soft coercion."

But few objected to a "soft energy path." With worries about global warming encouraging many to cut back on the burning of hydrocarbons, Canada made investments in the development of alternative energy sources on the supply side and conservation on the demand side. Because the installed base of both generating capacity and electrical appliances was vast and slow to turn over, the shift toward the soft path was slow in coming. But once the benefits of clean, cheap energy became apparent to all, the steady march of incremental replacements was unstoppable.

On the supply side, wind worked well in the plains. Small and highly efficient gas turbines worked well in the eastern provinces. By 2020, fuel cells were working pretty much anywhere that people wanted locally generated power. The old model of highly centralized power generation with an extensive grid of transmission lines gradually gave way to a highly distributed model of local generation and co-generation.

On the demand side, information served as a substitute for energy. Not that you could light your lights or heat your house with bits and bytes directly; but sensors and computing power served to reduce demand by making many appliances *smarter* and less wasteful. Lights turned themselves off when people left rooms. Houses were designed to use less energy. Transportation was rendered more energy-efficient by the application of smart design. Information increased efficiencies wherever energy was produced or consumed.

Canada was not alone in taking advantage of technical breakthroughs in energy technology, but building on its social cohesion, Canada made more rapid progress than most in implementing changes that required long lead times. As a result, Canada reaped the economic rewards of the first mover. Global firms looking for clean, cheap energy chose to site new facilities in Canada. Despite the acceleration of economic growth, environmental performance stats for Canada in 2025 showed "by far the best decade ever" on all factors.

Cheap, clean energy drove industry, industry drove the economy, and a vibrant economy supported social programs, better health care, and improved education. A better-educated workforce brought higher value-added industries to Canada, which put less strain on the natural environment than, say, aluminum smelters. By shifting from energy-intensive industries to brain-

intensive industries, Canada lowered its demand for energy, and hence its price, giving a further boost to the economy.

Energy, economy, society, environment, quality of life, and quality of workforce—by 2028 these wheels within wheels were turning with a clean efficiency that was the wonder of the world. The 1950s witnessed the "German miracle" as Germany rebuilt itself after WWII. During the 1980s people spoke of "the Japanese miracle." Now it was "the Canadian miracle," that showed up on the cover of *The Economist.* Would it be more sustainable than the others?

Early Indicators:

- Decrease in fundamentalist thought globally
- Less time spent in security at airport line-ups
- Many land claim settlements for First Nations
- Tax incentives for alternative energy
- Courses in architecture schools on how to design for energy efficiency
- Progress in fuel-cell technology
- Successful resolution of claims of aboriginal inheritance
- Environmental health increases

Lower-Left Quadrant – *Muddling Through*

- **Low magnitude of challenge**
- **Low degree of social, political, and environmental well-being**

By 2028, most remaining Canadians would have been happy to count nuclear wastes as one of their biggest problems. The preceding decades had tested the strength of Canada's civil society and found it more fragile than any had suspected. Civility, the rule of law—these civic virtues had formed the very backbone of Canadian culture, so much so that they had been taken for granted. But history had surprises in store.

Relying on the solidity of its core institutions and civil society, Canada had always opened her arms to immigrants. With people from dozens of different countries living together in relative harmony, Montreal and Toronto prided themselves on their cosmopolitanism. In the 1990s, Vancouver welcomed a wave of Chinese who were nervous about Hong Kong's transition from British rule to unification with greater China. But that wave was nothing compared to the hundreds of thousands who fled China during the following decade when the Communist Party imploded. Nor was the country really prepared for the waves of refugees from Africa following the drought in the Sahel.

Canadians had felt their identity threatened mainly by their neighbor to the south. But as immigrants filled lower paying jobs, the best and the brightest of Canada's college graduates sought better paying jobs in the U.S. What with the combination of brain drain to the south, and immigration from China and Africa, by 2010 the Canadian census revealed a demographic profile of a country transformed.

Canada's demographic transformation might have been smooth if the economy had held up, but a series of hits left the country tottering between recession and depression. First it was the destruction of the Pacific, Atlantic and Great Lakes fisheries by a combination of warming ocean temperatures and illegal over-fishing. Then the four-year drought in Saskatchewan led farmers to vacate the land.

Facing massive deficits, the Martin government proposed US-Canada-Mexico talks to unify North America. This further blow to Canada's already frayed sense of national identity led to rancorous disputes in Parliament where other issues begged for resolution, energy policy chief among them.

Nuclear energy moved several steps forward, and then fell further back. Falling water levels in the Great Lakes and economic hardship in Ontario led to initial acceptance of upgrades to nuclear power plants. But following Martin's defeat, the new NDP government put an end to the nuclear liability exemption. Sourcing uranium became surprisingly problematic, given its abundance in Canada. A mine near Kanesatake was shut down after a 6-year battle ended with victory for the Mohawks. When contamination from another uranium mine showed up in Kanesa Lake, the community mounted a fierce legal battle, which dragged on so long that local residents threatened violence as an alternative.

Several environmental NGOs linked arms with labour unions to oppose nuclear power. Once the government withdrew subsidies for the nuclear industry, the end of nuclear power in Canada was virtually guaranteed . . . if the industry could afford to shut down. Remaining operators made the argument that decommissioning the plants would be more expensive than continuing their operation. Ontario Power Generation had written off billions spent in failed efforts to restart reactors that had been shut down when the industry stuttered five years earlier.

With the economy still dragging through the century's second decade, energy demand was increasingly satisfied by a complex mix of decentralized sources. The steel industry bemoaned the loss of nuclear baseload generation, but most other energy customers got what they needed. With the development of new techniques for the sequestration of carbon at low cost, the burning of coal increased. With help from US investors, oil sands production reached an all time high in 2015. The price for those US investments? Total control over Canada's energy policy. Ongoing talks on North American Union eventually stalled over the insistence by the US on control over all energy resources.

Poverty and health problems in aboriginal communities drew little sympathy from either federal or provincial governments. Ottawa reneged on most of its responsibilities to Aboriginal peoples. Negotiations over land claims ceased altogether. Disparities between the rich and poor were growing to unprecedented levels. Low-income new Canadians were draining what little remained in the welfare budget. Investments in new energy systems had to be postponed. With energy prices escalating, Alcan laid off thousands of workers when it shut its last Canadian smelter in 2018, since it could make more money selling the energy from its hydro facilities in Canada on the wholesale market than it would by using it to produce aluminum. The Canadian economy continued to suffer.

In 2020 an NGO-led gathering set out a plan for Canada's recovery. A citizen's coalition proposed a radical national energy strategy based on conservation and distributed sources. Whitehorse was held up as a model and received an award for their local energy system. But these unconventional efforts to end-run the established government and its infrastructure came as too little too late. Save Canada? Whose Canada? Canadians had become polarized along too many different spectra: Old Canada vs. New Canada, rich vs. poor, east vs. west, Francophone vs. Anglophone.

The depopulation of the prairies due to the continued drought caused an overload and collapse of the remaining centralized energy systems in Ontario and British Columbia. With a fragmented society and a soaring national debt, plans for the restoration of the energy system had to be deferred for lack of funds.

A twenty-year test of a nuclear waste management prototype that had been started in 2005 was declared successful . . . but lack of funding meant that there would be no transition from prototype to full-scale implementation. What nuclear waste remained following the shutdown of the industry would have to sit until someone, sometime could afford to pay the bill for its long-term management.

Early Indicators:

- GNP numbers by province reflecting depopulation of troubled areas
- Histogram of generator sizes showing progressive decentralization of energy sources
- Attitudes toward immigrants favorable at first, then shifting
- Migration numbers, high initially, then decreasing
- Mood of pessimism
- Decreasing investor confidence
- Food shortages: crops failing, fisheries declining, drought

Upper-Left Quadrant – *Murphy's World*

- **High magnitude of challenge**
- **Low degree of social, political, and environmental well-being**

Murphy's law says that what can go wrong will go wrong. Murphy must have been a Canadian.

Back in 2008 it seemed like a reasonably good idea for Canada to accept reprocessed plutonium as part of a global non-proliferation program. Sure, there would be management problems. But better to manage it with safe hands than to leave a lot of plutonium in places where rogue nations or terrorists might get their hands on it. Besides, managing those wastes would provide thousands of jobs for Canadians. Somebody had to take the job of garbage man for the globe's nuclear energy industry and Canada, with its history of social stability, was a better candidate than most.

But several things went wrong with this "good idea." For starters, the job of managing nuclear wastes got much harder—and more expensive—after terrorists attacked a reactor leaving hundreds dead and injured. Canada had already cut deals with both Russia and the US for the management of wastes for a set price but it gradually became clear that the cost of doing so—given additional security concerns— would greatly exceed the agreed price.

If the economy were strong enough, the costs of security, storage and disposal might have been sustainable. But throughout the first decade of the century, irregular and unpredictable spasms of terrorism took their toll on economies around the world. The war between Pakistan and India gave rise to terrorist incidents against Hindus in other parts of the world. Muslims in Indonesia, Malaysia and even Canada were targets of Hindu reprisals. Countless disputes flared up along Russia's southern border. Islamist radicals in Western China joined Tibetans seeking separation from the Middle Kingdom. By 2015, Samuel Huntington's book, *Clash of Civilizations,* looked like a very prescient piece of futurism.

Canada's decision to take on the job of managing more than its share of global nuclear wastes had been made on the premise of the increasing globalization of cultures and economies. That had certainly been the trend throughout the final decades of the 20th Century. The end of the Cold War, the unification of Europe, NAFTA, the shrinking of the globe by the rapid growth of the internet—all signs had pointed toward an increasingly interdependent world order in which each nation would seek to make its highest and best contribution to the whole earth in order to reap the greatest benefits from the whole earth. For Canada, given its social stability, technological sophistication, and vast unpopulated areas . . . the job of nuclear waste storage and disposal seemed to make sense. It drew on Canada's "core competences," its comparative advantages in a global economy. But 9/11 turned out to be more than a speed bump on the road to further globalization. With 20 years of hindsight, 9/11 looked more like a U-turn in world history.

By the third decade of the 21st century, independence and self-sufficiency had replaced inter-dependence and trade as drivers of economic sustainability. Parts of Canada that had barely joined the 20th Century looked good in the new (or very old) order. Those who were not dependent on the electrical grid could use the technologies of self-sufficiency to live very comfortable lives. Stewart Brand's *Whole Earth Catalog* came out of retirement and gave the lie to the title of its previous edition, *The Last Whole Earth Catalog.* Three decades later there was tremendous demand for knowledge of all the tools necessary for living self-sufficiently.

Because life in Canada was a whole lot better than life in many other parts of the globe, real estate values held firm. Health care, education, entertainment, manufacturing—most everyday activities maintained their daily schedules. This was not a new dark age and there were no cataclysmic catastrophes. But the bargain that had been struck with the rest of the world, based on

the premise of increasing globalization, turned out to be a bad one, getting worse as the world's many nations and cultures pulled in toward themselves. The retrenchment from globalization was as gradual and incremental as the growth of globalization during the 20th Century, but its effects on even the most fortunate countries like Canada were real and unmistakable: not as many low-priced imports, fewer markets for exports, but more local industry producing goods that used to be imported.

Hard times abroad translated into hard times at home, especially for those who needed help most. While some from the First Nations emerged as teachers and guides for living more self-sufficient lifestyles, aboriginal politics reflected Canada's own internalization of the clash of civilizations. The Canadian government broke several deals with First Nations and announced new sitings for the management of spent fuels. Some First Nations opposed nuclear storage in Algoma and began a nationwide campaign of resistance and even sabotage when the government turned a deaf ear to their opposition.

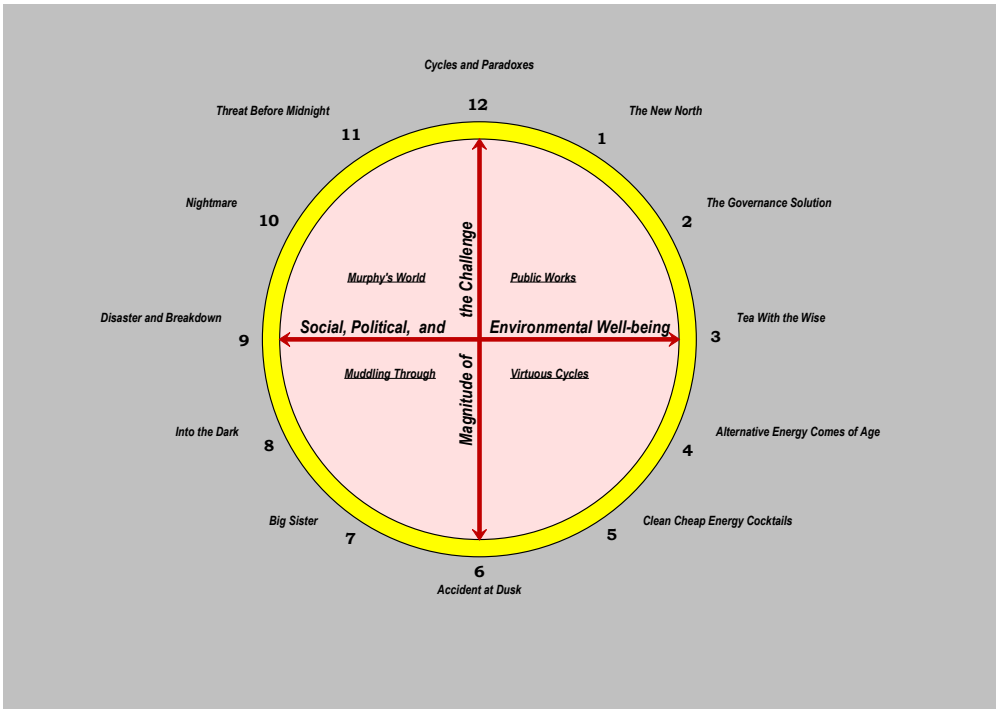
When a fourth shipment of nuclear wastes disappeared in Manitoba, the government still denied any threat of its acquisition by terrorists. But most people had long since ceased believing what they heard from Ottawa. The traditional respect with which Canadians had viewed their public servants had turned to fear and loathing. With the threat of terror unremitting, privacy was a distant memory. The long arm of security reached into all transactions and communications media. Predictably, the government denied any relationship between high radiation levels and massive die-offs in the Great Lakes fisheries. Nor would the government accept any responsibility for increasing cancer rates in many communities.

When a massive earthquake struck southern Ontario in 2028, many people decided that it was time to relocate from vulnerable urban environments. With 10% of Ontario's population on the move, Alberta closed its doors to further immigration.

Early Indicators:

- Declining public respect for government—low voter turnout
- Disputes between US and Canada
- Failure of global governance
- Inter-provincial disputes
- Reduced international trade:
    - Increased trade barriers
    - Increased subsidies
- Canada leads in nuclear waste disposal technologies
- Relaxation of environmental regulations and/or lack of enforcement
- Back to the land movement--number of hunting licenses, survival skills classes increase

V. 175-Year Scenarios



The twelve 175-year scenarios branch off from the four 25-year scenarios and, as such, illustrate longer-term extensions of the logics dictated by the scenario matrix. History hardly ever moves in one direction very long, however. Twists and turns, ups and downs, cycles, disasters, and responses to disasters give real history a circuitous course. We can be quite sure that the next 175 years will not remain restricted to any one of the four quadrants of the matrix. Nevertheless, the kind of *big history* drawn by figures like Edward Gibbon, Oswald Spengler and Arnold Toynbee confronts us with broad vistas and vast sweeps like the decline and fall of the Roman empire, or the Dark Ages, or the rise of the West following the Renaissance.

As we contemplate the span of seven generations, it's possible to imagine each of the 25-year scenarios branching in fundamentally different directions that illustrate or exemplify the logical premises with which their first 25 years began. The real world may jump back and forth between several of these 175-year scenarios. Granting the likelihood of such complexity, it's still worth exploring what it could mean to play out the basic premises of the 25-year scenarios for another 150 years.

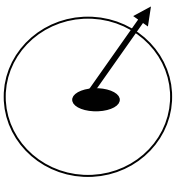
Models rely on simplification. The map is not the territory. If a map or model were exactly equivalent to the territory it maps or models, it would be useless. A map of Canada as big as Canada would never fit in the glove compartment of your car. The map is smaller and simpler than the territory it represents. So, likewise, our scenarios, our models of the future, must simplify in order to be useful.

The following scenarios rely on the simplifying elegance of a clock face. Consider each 25-year scenario as filling one quarter of a clock face. Then consider two extensions of the scenario, one that moves faster along the vertical axis and slower along the horizontal, the other moving faster along the horizontal, slower along the vertical. This schema is easily represented by imagining,

say, a one o'clock and a two o'clock vector beyond the upper-right quadrant of the scenario matrix; likewise, four o'clock and five o'clock trajectories beyond the lower-right quadrant; and on around the clock face to 7, 8, 10 and 11 o'clock scenarios. To complete the circuit around the clock face, four additional scenarios extend beyond the matrix at 3, 6, 9 and 12 o'clock.

Each of these twelve 175-year scenarios has a distinct logic. Reality will never be so consistently logical. But arranging these twelve scenarios in this clock-like manner allows us to model the unimaginable complexity of the coming centuries in a way that might make the task of testing different solutions to the challenge of nuclear wastes a little more manageable. In addition, by covering all 360 degrees of the clock face, however contrived these twelve all-too-straight vectors may be, we come as close as we reasonably can to covering a complete sweep of combinations of fast or slow, up or down, right or left along the axes of critical uncertainty. Given that there can never be a completeness proof for having thought of *everything,* this 360-degree sweep has a certain comprehensiveness to recommend it.

One O'Clock – The New North



Extending *Public Works* to 2175, economic growth produces a level of energy demand that makes it impossible to reduce Canada's dependence on nuclear energy. At the end of our 25-year scenario, nuclear accounts for 10% of the energy mix. Environmental policies and the lack of a suitable technology for carbon sequestration restrict the development of oil sands. Progress toward a hydrogen economy is steady, but slower than some might have hoped, so nuclear energy is called upon to satisfy the demands imposed by economic growth.

A vector at one o'clock rather than two o'clock suggests an increase in the technological challenge that is *more rapid* than the increase in society's capacity to cope with the challenge. But unlike the left side of our matrix, the one o'clock vector suggests that there *is* some improvement in society's capacity to deal with the challenge of nuclear wastes. Canada's institutional infrastructure remains viable, with modifications, throughout this scenario. Indeed, attention to the relationships between humanity and nature leads to greater sensitivity to *bio-regional* governance. Some provincial boundaries are redrawn accordingly, but the entity known as Canada remains intact.

In this scenario, the materialist values of consumerism spread from the OECD countries to the rest of the world. Billions of people remained outside of the consumerist economy in the 20th century. During the 21st and 22nd centuries, most join the march toward economic prosperity—good news for more humans, but bad news for the carrying capacity of the earth.

The end of the Pax Americana that reigned supreme through most of the 21st century brings with it a series of small wars but no cataclysms. New disarmament agreements are proposed, but no lasting agreement is achieved. With energy infrastructure one of the favorite military targets, the security risks associated with nuclear power increase.

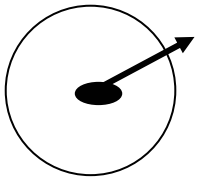
Science and technology continue to advance in ways impossible to imagine in detail . . . but in this scenario the broad brush logic is one of miniaturization (e.g., nanotechnology) and decentralization, permitting a broad distribution of smaller population centers. Mega-cities proliferate during the first fifty years of the scenario, especially in the developing world. But the development of mini-nukes and fuel cells makes it possible for people to settle in places that used to be considered too far off the grid of energy infrastructure to be economically viable. As growing numbers of mega-cities reach uncomfortable limits of population intensity, people use

the new technologies of local energy production to create new communities in places formerly regarded as uninhabitable.

The Yukon, the Northwest Territories and Nunavut are the new frontier, as chic as Montana and Idaho were in the early 21st century. Just as air-conditioning created the "New South" from Atlanta to Phoenix during the mid-20th century, so new forms of distributed, local energy production produce the "New North" reaching ever further north during the 21st and 22nd centuries. Ecologically and energetically self-sufficient communities spring up using large amounts of locally produced energy to power agriculture, heat homes, and drive vibrant local economies. At the same time, the natural habitat suffers as humans populate what had been wilderness.

While there is active trade in information resources through a broadband communications network that makes the internet of 2010 look primitive, products with mass—molecules rather than bits—tend to be produced locally. Early in the 22nd century, information technology and nanotechnology combine to produce the first working prototypes of "assemblers"—machines that allow you to put just about any raw material in one end, and get out the other end just about anything you can write a program to design. With progress on various generations of assemblers advancing rapidly between 2130 and 2160, shipping even small masses of molecules becomes uneconomical by comparison with production on-site. But all this local production uses vast amounts of energy, and the amount of nuclear wastes is constantly increasing and getting more widely distributed.

Two O'Clock – The Governance Solution



In this scenario, social and economic developments outstrip the rate of increase in the challenge of dealing with nuclear wastes. The challenge is increasing—energy demand continues to rise—but our social and organizational skills are developing even faster. There's no miracle cure for the transmutation or re-use of nuclear wastes, hence the increasing challenge. Instead, this scenario envisages progress in social, economic, and political organization such that people learn how to live together in ways that reduce the threat of war and/or terrorism.

By 2030, the wages of economic inequality are weighing heavily on the world's most advanced nations. As the rich get richer, the costs of security claim an ever-larger share of their wealth. Walled cities, gated communities, and increasingly onerous airport security systems are constant reminders of the threats of terrorism from those who remain at the bottom of the economic pyramid.

During the fourth and fifth decades of the century, social scientists and economists finally learn what they need to know about nation building and economic development. And they get help from those they are supposed to be helping. By opening up two-way communications with grassroots organizations, social scientists learn how to *implement* their ideas—how to move from theory to practice. From pre-natal health care to basic education for all, from land reform to building the institutional infrastructure for civil society, the rich nations of the north reach out to poor nations around the world in ways that are both respectful of local cultures and genuinely helpful.

In Canada, the global experience in land reform leads to a re-opening and successful settling of long-festering land disputes. An increase in grassroots, participatory democracy creates opportunities for First Nations people to demonstrate sustainable practices in land use.

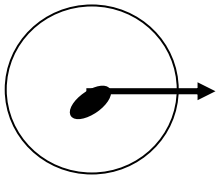
By the end of the 21st century, the old measure called GDP has been replaced by general progress indicators that render full life-cycle environmental and social costs/benefits information instantly transparent to consumers. Tax reforms also help to internalize environmental costs. As a consequence of the new transparency in both public and private sectors, waste is expensive. Businesses, governments, and consumers have strong incentives to conserve energy or use non-polluting, renewable sources of energy.

While population controls help to limit humanity's demands on the earth's carrying capacity, the widespread success of social and economic development continue to exert upward pressure on energy demand. Nuclear continues to be a necessary part of the energy mix. Fortunately the threat of war and terrorism has been significantly reduced by the mid 22nd century, so both nuclear generating capacity and spent fuels are considered safe from malicious use or attack.

Global governance linked with local self-determination is a reality by 2150. The combination of informational transparency and local autonomy allows individuals and communities to make economic decisions that don't levy costs on people far away in time or space—future generations or the geographically distant.

Science hasn't succeeded in delivering energy for free. Nor have we learned how to render wastes completely safe. But by 2175, advances in social, economic, and political practice are allowing people to rest a little easier with nuclear wastes than they did back in the risky world of the 21st century.

Three O'Clock – Tea With the Wise



This scenario is driven mainly by a shift in values: Away from the kind of consumerist materialism that places a heavy burden on the earth, and towards values that honor harmony with nature's ways and sustainable economics. Given the choice between megawatts and negawatts (conservation), more and more nations choose a "soft energy path," in the words of Amory Lovins, whose work has been embraced and extended by many in Canada.

During the first fifty years of this scenario, biotechnology and medical science combine to extend the normal human lifespan to 180 years and rising. Rather than creating massive problems for social security and retirement systems, the demographic shift toward a more mature population produces a society of experienced, temperate and well-educated volunteers who devote much of their "retirement" energies to giving back to society (as argued in Theodore Roszak's book on the graying of society, *America the Wise).*

By the 22nd century people look back at gas-guzzlers and SUVs of the early 21st more or less the way people of the 20th century looked back at the practice of slavery in the 19th. "How could they not have seen the damage they were doing? How could they have been so morally and environmentally blind? Didn't they know that their short-sightedness would come home to haunt them—or, more importantly, *us*?"

Old and concentrated populations like the Japanese taught an aesthetic of minimalism and frugality. A rapprochement between eastern and western values produced an amalgam that

allowed a high quality of life on a lean diet of energy and materials. “Buddhist economics,” they called it.

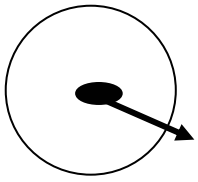
By the dawn of the 22nd century, societies around the globe have been transformed by a sublimation of their economies: from a heavy throughput of minerals and energy to a more sublime mix of information, education and entertainment; from an economy based on products to an economy based on services and experiences. Energy demand has dropped to less than half of what was consumed in the year 2000. Wisdom, it turns out, requires very little energy for its realization.

Nuclear wastes remain as a legacy of the bad old days when people did not know how to limit their energy demands. By 2150 we see the beginnings of a nuclear priesthood organizing to keep watch over this detritus of an earlier age. No new nuclear plants have been built for over 100 years, but no technology has been discovered that would eliminate the danger of exposure to radioactive isotopes, so human beings must continue to remain vigilant lest the mistakes of the past inflict damage on the present or future.

The “Witnesses”, as they are called, do not look kindly on anyone who suggests a new round of nuclear energy production. But unlike the righteous critics of old ways who dominated the debates in the early 22nd century, the Witnesses of 2175 experience compassion when they think of those who, 200 years earlier, drew heat and light from uranium. Being of an average age around 150, therefore born around 2025, they count their own grandparents among those who simply didn’t know any better at the time.

With people living to such ripe old ages, one of the biggest challenges is over-population. The Witnesses are called upon to say who shall and who shall not bear children. Because children are so rare, they are very precious. The teaching profession has replaced law, medicine, and investment banking as the highest paid. Only the smartest, wisest and most compassionate members of society may spend long hours in closed quarters with the young, who are taught early on how to husband energy very carefully.

Four O’Clock — Alternative Energy Comes of Age

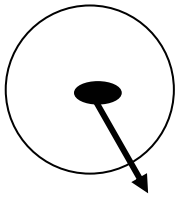


Back in the early 21st century, many policy analysts scoffed at the prospects for so-called “alternative energy” — which included everything from solar energy from photovoltaics and passive solar, to geothermal and wind. The photovoltaic cells were too expensive, took too much energy to manufacture, and once in place, delivered too little energy, to say nothing of the fact that, in much of Canada, there was too little sunlight to begin with. Likewise windmills, which had been on a path of highly engineered improvement ever since their picturesque ancestors dotted the dikes around Holland, still cost too much and remained too dependent on fickle winds. Geothermal worked only in a few places where sources of heat were sufficiently close to the surface. Theoretically it seemed like a fine idea to harness renewable sources of energy . . . but in practice, none of the available solutions came anywhere close to hydrocarbons or nuclear as sources of large quantities of reliable, low-cost energy. And as far as conservation was concerned, the alternative energy industry could not shake the memory of US President, Lyndon Johnson’s quip that conservation meant, “freezing in the winter and sweating in the summer.”

But science marches on. As long as alternative energy labored under the legacy of looking like a low-tech alternative to a high-tech energy grid, there was little hope it could pose a meaningful alternative to massive, centralized generating stations. But a series of scientific advances—not one, but many—gradually raised the efficiencies of almost all forms of alternative energy. Advances in nanotechnology both reduced the costs and raised the output of photovoltaic cells. Advances in materials science made it possible to produce blades for windmills that were both stronger and lighter than anything available in the early 21st century. Increasingly sophisticated combinations of sensor technology, information processing, and the right-sizing of electric motors made for orders of magnitude improvements in the energy efficiency of automobiles, air-conditioning, heating, ventilation, pumps, lighting, computing . . . just about every source of demand for electric energy.

No single breakthrough made the difference, but throughout the 21st century, alternative sources of energy gradually contributed a greater and greater portion of the energy mix. Because alternatives provided a cleaner source of energy than hydrocarbons, the Canadian government introduced tax incentives that favored renewables over gas and oil. Though nuclear continued to provide a significant part of the energy mix through most of the 21st century, by the end of the century the success of renewables and conservation was such that both hydrocarbons and nuclear tailed off toward the kind of "negligibility" that alternatives suffered at the beginning of the century.

Five O'Clock – Clean, Cheap Energy Cocktails



In this scenario, social stability arrives more as a result than as a cause. Social tensions are reduced by technological developments, including a solution to the problem of nuclear wastes. By 2050, scientists have discovered ways to achieve the transmutation of nuclear wastes fairly easily and economically. Some spent fuels are more easily neutralized, others reprocessed for another round of exploitation. The new transmutation technology works at small scale on site, so the challenge of transporting nuclear wastes also disappears. Because transmutation is so easy and cost-effective, much of the "waste" produced during the 20th and early 21st centuries is now regarded as fuel. This is the world of "guilt free, clean energy that is too cheap to meter."

Given the availability of virtually infinite amounts of energy at almost no cost, economies around the world are thriving. In Canada, as well as in other northern climates like Finland, Norway, Sweden and Russia, the availability of nearly zero-cost energy is a great boon to social and economic development.

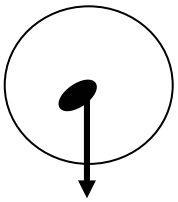
With nuclear energy now rendered substantially safer by advances in the basic science of nuclear physics, oil, coal, and even natural gas are used as fuel only in special circumstances. Oil is still highly valued as a lubricant. Because oil is nonrenewable, people of the 22nd century look back in amazement at its earlier uses. "You mean they actually *burned* this stuff? And polluted the air in the bargain?!"

Clean, cheap energy fuels a new renaissance. With capital to invest in education, health care and the arts, societies all over the world enjoy a flowering of culture. Just as the Italian Renaissance reawakened the spirits that spawned the great achievements of ancient Athens, so the 22nd century witnesses a kind of Cambrian explosion of new species, new genres, new varieties of art and music undreamt of in the 18th through 21st centuries.

Toronto, known for its skill at combining the old with the new, is one of several global centers of creativity in the visual arts. Calgary is the new Nashville, the home of a new genre of Canadian "country music." Vancouver becomes known a showcase for architecture inspired by a hybrid of Chinese and western influences.

Clean, cheap energy also helps to create a more equitable economy. Back in the 20th century, poor people spent a much higher proportion of their income on energy than rich people did. Now that they are freed from paying bills that ate up such a large share of their incomes, the lower quintiles on the economic ladder have more opportunities to invest in products and services for self-improvement rather than subsistence. Relieved from the struggle for basic necessities, e.g. energy, people with lower incomes are less likely to get trapped behind the eight ball of credit card debt and high interest payments. The gap between the rich and the poor, a seemingly insoluble problem during the 21st century, simply dissolves with the discovery of clean, cheap energy.

Six O'Clock – Accident at Dusk



In this scenario, the challenge of nuclear wastes is low because nuclear energy has been abandoned. A nuclear disaster early in the scenario leads to a worldwide adoption of a no-more-nukes policy. Existing plants are gradually shut down as age and embrittlement render them ever more dangerous and obsolete. We see the danger of aging nuclear plants after an accident far worse than Chernobyl. By 2035, nuclear energy enjoys a reputation about as popular as the idea of eugenics following the Nazi holocaust. Call it, simply, "bad science."

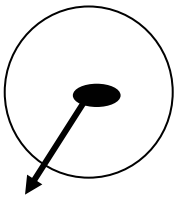
"Never again," is the refrain associated with nuclear energy. People realize that a bad accident involving existing nuclear wastes could be as damaging as the meltdown and explosion of a nuclear reactor. Criticality—the attainment of critical mass by wastes in close proximity—looms as a possibility when an earthquake fault is discovered near one storage facility. Given the appalling evidence of radiation poisoning following The Accident, the public sense of urgency about nuclear wastes escalated to a level much higher than before The Accident. Everyone acknowledges the need, and the taxpayers would be willing to compensate communities that are willing to have wastes in their back yards. But no amount of money is enough to convince parents to endanger their children.

The abandonment of nuclear energy leads to an even greater dependence on fossil fuels. Coal and oil sands increase their share of the energy mix between 2060 and 2080 . . . and the atmosphere shows the consequences. Despite efforts to sequester carbon, the greenhouse effect leads to global warming, the polar ice caps melt, ocean currents shift and rapid climate change kicks in, but not as predicted by the simplistic models of the early 00's. The huge influx of freshwater in the Arctic has brought the thermohaline conveyor belt to a near standstill, stopping the Gulf Stream, which used to bring huge amounts of heat northward from the equator. By the last decade of the 21st century, many Canadians and Europeans find themselves freezing in the dark.

Unwilling to revert to nuclear energy, and reluctant to burn more hydrocarbons, Canadians find themselves returning to subsistence-based lifestyles. Since climate change affects different parts of the earth in different ways, the early 22nd century is a time of mass migrations and political instability. Canada's population shrinks to less than half of what it had been in 2050. Drying of

the southern prairies moves what little remains of agriculture to Peace River, but lack of good soil causes tremendous increases in food costs.

The cooler, dryer climate in Canada also leads to a decrease in water levels in the Great Lakes and drastic reductions in the use of the St. Lawrence Seaway. Businesses that used to depend on that traffic shift to the Maritime Provinces. By 2175, Canada is a frozen shell of the nation it once was.



Seven O'Clock – Big Sister

This is a world in which worries about safety and security lead to a cure worse than the disease. The unpredictable staccato of terrorist actions during the early decades of the century put populations on perpetual high alert. Sabotaged power lines, urban bombings and aerial assaults on nuclear generating plants create a level of fear and paranoia that fundamentally changes the tenor of everyday life.

Evidence from the accounts of captured terrorists made it clear (in retrospect) that initial efforts at counter-terrorism were, in fact, counter-productive: Efforts to contain and eradicate terrorism in places like India, Pakistan, Indonesia and the Middle East only served to instill a deeper resolve to bring down the infidel nations of the West. For each terrorist captured or killed, five or ten brothers, sisters or cousins stepped forward to take revenge. Like the many-headed hydra of Greek mythology, the menace seemed to multiply the more it was attacked.

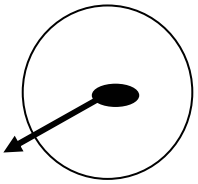
As anti-terrorist measures became more intense in hot spots like the Middle East, the world suffered a Diaspora of despair. Nations that had prided themselves on their cosmopolitanism—e.g. Canada—came to regret their long and relatively porous borders. By 2030, international travel had dropped to a tenth of what it had been three decades earlier. The restraints on trade were economically intolerable. Something had to be done.

By mid-century, technology came to what some considered a rescue. Sensors were everywhere. Smart dust sprinkled across landmasses could pick up traces of nuclear or biological weaponry in concentrations of less than one part per million. Massively redundant information systems correlated the data gathered from networks of sensors. Sub-cutaneous implants allowed the authorities to locate and track every human being on the face of the earth everywhere all of the time. By the end of the century, everyday life was like those brisk mornings after a fresh snowfall: You left tracks everywhere you went. No movement went unregistered or unanalyzed. Big Sister needed to know.

With the achievement of "Total Information Awareness" — a concept that had been proposed and ridiculed back in 2003 — humanity was rendered safe from terrorists. Certainly nuclear energy was safe, at least from terrorist attack. Because every one of its components all the way along the supply chain could be clearly located, identified, and fairly easily isolated, protecting each of the links in the nuclear energy supply chain was a piece of cake compared to protecting soft targets like homes, schools and marketplaces. Of course the sensors served as double-edged swords for the nuclear industry: While mines, generating plants and storage facilities were rendered safe from terrorist attack, the heightened sensitivity of the sensors created more concern about what, in an earlier era, had been regarded as "normal" releases of radiation.

Promoting nuclear energy was not the reason for the imposition of total surveillance. But once the technology of total surveillance had been developed and implemented—once Big Sister was part of the human family— humanity occupied a world that was tailor made for keeping nuclear energy safe from attack, but also tailor made for exposing "minor" accidents.

Eight O'Clock – Into the Dark



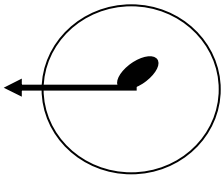
"Night" has fallen. Latter day Dark Ages have begun. Society has gone to hell in a hand basket, but not because nuclear wastes are so unmanageable. The challenge of nuclear wastes decreases from today's levels simply because energy demand is so low. This is an economic collapse scenario, possibly brought on by plague, possibly by conventional wars, possibly by environmental collapse. Whatever the cause, the human population on the earth is down to 3-4 billion people or less, living in conditions not much better than those of the 12th century.

While the volume of nuclear wastes is not increasing, this is a world of ill-educated scavengers and vandals, so what wastes remain from the 20th and 21st centuries are vulnerable to hunters and gatherers on the prowl. In this not-too-distant future, we can presume a degree of linguistic continuity and literacy such that the main criterion for signage is not that it be readable, but that it be convincing to people who distrust authority. To people hunting buried treasure troves of canned goods or cash, a sign that simply says, "Don't dig here!" may be interpreted as a challenge to dig precisely there. How better might the people of an earlier age have tried to keep others away from their hidden treasures?

In this "Mad Max" world of warlords and tribes there's little trace of civil society. It's dog eat dog . . . or man. There's no one left who knows how to operate a nuclear waste management facility, much less a generating plant. No more wastes are being produced, but existing wastes are hardly well guarded. In a world where disease, knives, and bullets are ubiquitous, the dangers of nuclear wastes are the least of people's worries because they are generally unaware of the danger. For that very reason, however, innocent as well as predatory people are constantly wandering in and out of radioactive danger zones.

As in the state of nature described by Hobbes, life in this new Dark Age is "nasty, brutish, and short."

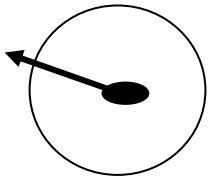
Nine O'Clock – Disaster and Breakdown



This is necessarily a very short scenario: All out nuclear war. *Boom!* Finis.

A longer story could be told about how the world approaches and slips over the brink into nuclear holocaust. Any number of such stories could be told, some based on strategic miscalculation, some based on malice, some based on accidents. We needn't point a finger at the nuclear energy industry as the source of fissionable materials. The point is that *after* such a holocaust, nothing that was said or thought or feared before the holocaust makes any difference whatever. There's no one to protect. All bets are off. No one is left to keep score.

Ten O'Clock – Nightmare



The world is at war, a limited war, but nuclear weapons are part of the arsenal. Plutonium and reprocessed nuclear wastes are at a premium. New members of the nuclear club who are desperate for munitions are targeting spent fuels.

In Canada, nuclear wastes that have been managed for decades must be guarded day and night by troops who are heavily armed and trained to kill anyone who approaches within half a kilometer. There are ugly incidents involving hunters and other innocents . . . but with the danger so high, who has patience to offer unknown prowlers the benefit of the doubt?

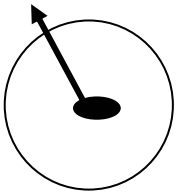
Aside from a nasty exchange of tactical nuclear weapons between Pakistan and India in 2045, no other bombs are detonated . . . until 20 years later when terrorists set off a warhead they trucked into Moscow. And then the Chinese took nuclear revenge against Japan in 2091 after the Japanese intervened in defense of Taiwan. Tensions remain high throughout the 22nd century. The very fact that three events involving nuclear weapons had not brought an end to the civilized world renders them "thinkable" and usable by others.

For decades after each of the detonations during the 21st century, epidemiologists tracked thousands of cancers and birth defects on maps that followed the downwind plumes of radiation. Chromosomal aberrations were alarmingly widespread in humans and other species as well. Photojournalists chronicled the horrors. Countless well-meaning efforts at disarmament followed each of the nuclear incidents, but none succeeded.

The winds of war continue to blow through the 22nd century. Game theorists and ex-generals gather at war colleges around the world to map the precise limits of so-called "conventional" warfare: How to win wars *without* resorting to the nuclear option? How to use *just enough* force, but not so much as to force your enemy to resort to the nuclear option? Because wars cannot be won with the kind of "overwhelming force" that might lead one's enemy to exercise the nuclear option, the history of the 22nd century becomes a tale of chronic and interminable, low-level conflicts.

Economies suffer. People suffer. Our descendents wonder why we ever made such a Faustian bargain with nuclear technology.

Eleven O'Clock – Threat Before Midnight



Back in the days of the Cold War between Russia and the US, the Union of Concerned Scientists used to maintain the image of a clock face with its hands approaching closer to midnight every time the threat of nuclear war increased. People forgot about that clock after the end of the Cold War. But in 2050, a New Union of Concerned Scientists brought it back, and for the next hundred years, its hands hovered perilously close to midnight without ever going quite vertical.

This could be a techno-disaster scenario, contrasting with the socio-political disaster of the previous scenario at 10 o'clock. But cataclysms do not last for 150 years. Let's not confuse this scenario with Six O'clock, which hinges on a super-Chernobyl. So instead . . .

The threat of nuclear wastes is high because economies are strong, energy demand is high, and science has failed to produce a solution to the technical management of nuclear wastes. The continuing availability of radioactive and fissionable materials makes the world a risky place. In this scenario *nuclear proliferation* is a genie well and truly out of the bottle. The human race cannot figure out how to put the toothpaste back in the tube.

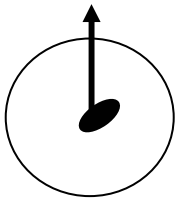
In 2040, Liberia becomes the fortieth member to join the nuclear club. The prospect of nuclear weapons in the hands of Charles Taylor's youngest and craziest son puts fear in the hearts of Liberia's neighbors, near and far.

While advances in technology and productivity allow many people to amass increasing wealth, the poor are still with us. The gap between rich and poor yawns so wide that hopelessness turns to revenge and terrorism. Some states accept totalitarian rule in order to maintain security. Freedom is a high price to pay for the wealth of a few, but the stakes are high—life or death by weapons of mass destruction.

The secular march of increasing technology tips in favor of terrorists. Technology allows a few people to do what it used to require many people to do, e.g., sack Rome, and so by its very nature serves the interests of the underdog in asymmetric warfare. The powers that be use sensors and the best available surveillance techniques. Privacy is a thing of the past. But even so, "soft targets" must be hardened, and anyone with anything to protect is living on the edge of nuclear insecurity.

Nuclear bombs never fall. Nuclear generating plants don't melt down. Containments of nuclear wastes remain unbreached. But life in the age of nuclear proliferation is life at risk. A sword of Damocles is poised to fall. People are very, very nervous.

Midnight — Cycles and Paradoxes



Early in the 21st century, advocates of nuclear energy realized that if they couldn't solve the problem of managing nuclear wastes, society at large might shut down the industry. At the same time, opponents of nuclear energy realized that if the industry came up with what appeared to be a satisfactory solution to the management of spent fuels, the nuclear industry would see it as a license to continue creating more nuclear wastes. Opponents of nuclear energy found themselves in a bind: On the one hand they wanted to ensure the safe handling of spent fuel—on ethical grounds; on the other, they wanted others to realize that no matter how safely wastes are managed, the risks remain unacceptable—on ethical grounds.

As the debate over what to do with spent fuels wore on, this bind became known as The Paradox. There seemed to be no rational solution. Like Zeno's arrow, which must first cross half the distance to its target, then half of the remaining distance, then half of the remaining distance . . . and so on *ad infinitum* leading Zeno to believe that it could *never* reach its target in a finite amount of time, the proponents of nuclear energy could *never* convince their adversaries that they had come up with a convincing solution to the management of spent fuels. But then Zeno's fabled arrow *does* in fact reach

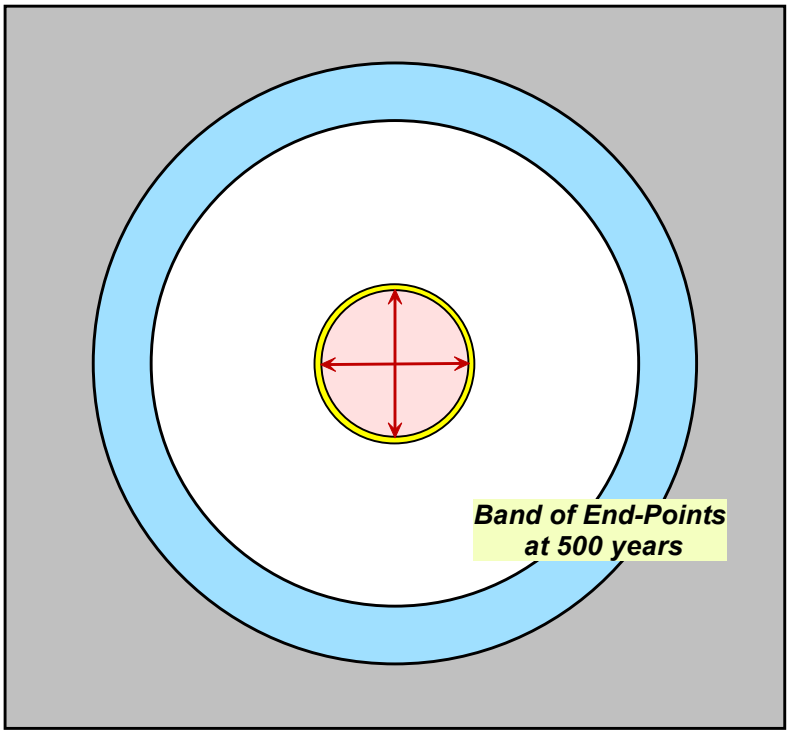
its target, and fairly quickly. So likewise, The Paradox of the management of nuclear wastes collapsed upon itself several decades into the 21st century. Various solutions were proposed and implemented by different nations. And just as Zeno's paradox of motion seemed to be refuted by the manifest facts of arrows reaching their targets, so the worries of nuclear nay-sayers seemed to be refuted by decades of uninterrupted safety in the management of nuclear wastes.

With criticism put to rest by decades of safe management, the nuclear industry gained confidence in its ability to handle radioactive wastes. As the century passed its midpoint, confidence turned to complacency and complacency turned to carelessness. Where the early years of nuclear power inspired PhDs in nuclear physics to devote their lives to the technology, by the late 21st century, working in nuclear waste management was as boring as being a night watchman. The industry had trouble attracting talent.

By the early 22nd century, the nay-sayers of the early 21st century, now long dead, were unfortunately vindicated. Canisters were corroding and those who watch the monitors were asleep at the switch. Cement barriers were being eaten away by anaerobic bacteria. High levels of radioactivity were showing up in aquifers. Trucks transporting nuclear wastes went missing. Fundamentalist Christian terrorists broke into a poorly guarded storage site and made off with dangerous quantities of weapons-grade materials.

After close to a century of safety, in an almost perfect reversal of The Paradox, success turned into failure. And precisely because the record of safety had been so convincing, the quantities of spent fuel that had been accumulated were now vastly greater than those that Canada had to deal with a century earlier. By the mid-22nd century, the challenge of managing nuclear wastes was higher than it had ever been.

VI. 500-Year End-points



The further into the future we look, the wider the range of possibilities, but the less we can say with any confidence. To accommodate both this increasing scope and the decreasing access to detail, the possibilities for the 500-year time horizon take the form of single paragraphs describing sixteen "end-points."

1. ECOLOGICAL COLLAPSE

Think about the collapse of the fisheries, the death of the coral reefs, the growth of the hole in the ozone layer, or Love Canal multiplied many times over and it's not hard to imagine that we cross a major threshold toward the collapse of the Earth's ecosystem. The change could be relatively slow, giving us time to react (leading to end-points like the colonization of space or the colonization of the oceans). The pace could be intermediate if kicked off by climate change or a reversal of the course of the Gulf Stream. Or it could be rapid and cataclysmic if prompted by Sun Microsystem's Chief Scientist, Bill Joy's nightmare: the confluence of biotech, nanaotech and infotech in some hacker's garage. The inadvertent production of a green slime or gray goo then multiplies out of control and takes over the Earth's ecosystem in a matter of days or weeks. However ecological collapse takes place, our descendents will not be happy with us. Future societies might have to cope with an environment far more hostile than the one we occupy today. They will shake their heads at our carelessness. Couldn't we see the consequences of our tinkering with the delicate balance that maintains life on this planet? If we destroy the systems that life depends upon, including countless species we now feed on, then we will become even more dependent on monocultures of remaining species to feed ourselves. In this not very

attractive future, one can imagine nutrition from capsules or a toothpaste tube replacing the pleasures of a four course gourmet dinner.

2. WATER WORLD

Oceans cover over 70% of the Earth's surface. If we muck up the land, the oceans could be our next frontier. But how do we relate this possibility to the management of nuclear wastes? Our shorter scenarios represent different worlds in which we are challenged to maintain the management of nuclear wastes under widely different conditions. Does *Water World* simply assume the failure of other management solutions? If so, then it's unlikely that ocean colonies would be powered by nuclear energy — a technology that had already proven itself flawed, or too hot for humans to handle. OR, do we assume that *Water World* is possible because we've learned how to generate nuclear energy from mini-nukes small enough to power ocean colonies? In that case, the management of wastes would still be necessary . . . but would now have to be managed at sea rather than on land. Or would abandoned continents serve as the garbage dumps for vibrant ocean communities? In either case, the usual suspects for land-based storage or disposal of nuclear wastes may be considered archaic and/or not worth worrying about. Instead, *Water World* illustrates one attempt by humanity to adapt to the consequences of our failure to manage nuclear wastes.

3. GUILT-FREE ENERGY

Even with advances in conventional-science-as-we-know-it-today, it's entirely possible that energy will simply cease to be a problem hundreds of years from now. The breakthrough could come from any of a number of possible sources: cold fusion, hydrogen, solar, or mini-nukes that are clean and safe. Whatever the source of clean, cheap energy, its consequences would include (a) a radical cost saving for supply chains throughout the rest of the economy with a resultant windfall in wealth; (b) the cleansing of the environment following a radical reduction in the burning of hydrocarbons—oil, coal, even natural gas. Cheap energy will solve many problems, but it will produce others: Because physical stuff will be so inexpensive to produce, we may produce too much of it. Given that we *can* travel almost anywhere for almost no cost, where *should* we travel? *Who* should travel? And *when?* A radical increase in our capacity to move people and manufacture things will require a new level of care and attention to the wise management of those new capacities. Otherwise, just as the miracle of individualized automotive travel led from a dependence on railroads connecting major cities, to the delights of the suburbs, and from thence to the horrors of commuter traffic jams, so too, the miracle of clean cheap energy could lead to travel-and-manufactured-stuff jams—too much of a good thing.

4. RAPID CLIMATE CHANGE

During the first several decades of this period, global warming continues in most of the world. The centre of the North American continent becomes hotter and dryer, with rainfall distributed very unevenly, causing both frequent severe droughts and floods, and seriously disrupting food production. The southern prairies become deserted. In Arctic regions the permafrost vanishes, severely impacting northern settlements and transportation. An abrupt change then occurs around 2150 as a result of changing ocean currents as the melting icecaps dilute the salinity of the North Atlantic. Northern North America and northern Europe cool rapidly. A period of very cold weather covers most of Canada for a hundred years. Populations retreat from the northern communities to which they had migrated earlier. Then, as greenhouse gas emissions continue to rise, with the melting of methane hydrates from the ocean floor, the warming effect fairly quickly becomes dominant again, and the

heartland goes through another devastating shift in climate. The huge and rapid transitions in climate mean that populations are frequently re-locating and long-term settlements are no longer possible.

5. POPULATION DECLINE

We can remain hazy about the causes of population decline—whether from war or plague or declining sperm counts or exceeding the earth's carrying capacity—but whatever the cause might be, it's worth entertaining the possibility of a 500-year future in which fewer human beings occupy the earth. Peace and prosperity could follow for those who remain. An economic transition might be required to avoid deflation. In either case, a smaller population would almost surely use less energy and, given the availability of electricity from hydro, might well have less need of nuclear. If a smaller population means fewer conflicts over resources, then we should be able to assume sufficient social stability to maintain continuous management of whatever nuclear waste sites are inherited from the 21st century.

6. THE POST-HUMAN FUTURE

In a "post-human" future, the human species has altered itself so much as to be barely recognizable. Whether transformed by a "singularity," or by bio-technology, or by some combination of silicon implants, the bipeds who walk the earth in 2500 are very different from the bipeds of today. Given the logic of the singularity—that it is in principle impossible to say much about what lies on its far side—it would be foolish to describe in any detail what post-human life would look like. Part of the point of describing this end-point is therefore to suggest the possibility of a discontinuity so radical that we need to think about our responsibility to future generations should humans become creatures radically different from us.

7. NEW TRIBALISM

One could imagine only the decline to tribalism, or a possible return from tribalism, but in either case the world must weather what could be centuries of anarchy. The threat of such a reversion to tribalism consists in the loss of the expertise and organization necessary to maintain any kind of technologically sophisticated infrastructure or equipment. This end-point must therefore be counted among those in which we cannot assume enough social stability to manage any nuclear waste sites that require continuous management.

8. COLONIZATION OF SPACE

Unlike *Water World*, this end-point suggests access to new territory, not for mass migration, but to supplement the carrying capacity the home planet. Space Solar Power Satellites beam down converted sunlight directly into the global electricity grid. New human colonies are established in high orbiting habitats, as well as on the Moon. Several industrial consortia have staked claims to large numbers of near Earth asteroids and are producing fuels for use in the growing space industry. A new venture is beginning to send down high value products on the space elevator which went operational in 2201, including, but not limited to super pure quantum crystals. While the population of Earth has stabilized and begun to turn downward, the off-planet birth rate has resulted in over 20,000 people living elsewhere, many of whom have never set foot on Earth. Can the trends grow to relieve the burden on Earth's natural resources permanently, or is this a lull before those off-world begin exercising their

new muscle and negotiate onerous trade terms? An Us vs. Them mentality seems to lurk in the background.

9. SECOND REFORMATION

This end-point revolves around the idea that our fascination with technological inventions should not blind us to the possibility of some new social invention. After all, democracy is a human invention, not something given to us by the laws of nature. Might there be some further social invention that would change the way we relate to one another as fundamentally as democracy altered the social relationships under monarchy or tyranny? Since that new social system has not been invented yet, it's hard to say much about what it would look like . . . but the possibility presents itself merely by virtue of a quick look over the last 500 years of social history: socio-political relations are as much subject to change as are technologies when you take a sufficiently long view.

Another source for this end-point (as well as the next one which is driven by a fundamental change in values) is the rich tradition of utopian literature, from Plato's *Republic* and Thomas More's *Utopia* to the works of Robert Owen, Ralph Bellamy and Ernst Bloch. Throughout history there has been a steady stream of thinkers who have imagined societies where justice, kindness and organizational efficiency combine to create a virtual heaven on earth. Given the range of utopian blueprints available in the literature, why is paradise so elusive? Why has there been no experiment in communal living that produced such happiness that others would copy the pattern? Any effort to look at the next 500 years of human history would be deficient if it neglected the possibility of further quests for utopia, even one that is successful. Assuming that a new social order works better than our current social order—else why would we trade the old for the new—this end-point must count among those in which we *can* assume a stable institutional infrastructure for the continuous management of nuclear wastes.

10. FUNDAMENTAL SHIFT IN VALUES

Could we see a fundamental change toward values that are less materialistic and more in tune with Mother Nature? Such a shift needs a new 'driver,' some new motivation. The driver might be quasi-religious. Such a future assumes that people are motivated in ways that are significantly different from what we take to be "human nature" today. What could bring about such a change? A new Messiah? The invention of a new social order, as in the last end-point? A bio-technological re-engineering of the human genome that would push this future toward a "post-human" future? Or could something as simple as a new breakthrough in child-rearing practices produce human beings who behaved differently toward nature and one another? We know very little about why values change when they do change, and for that very reason it's only prudent to imagine that values *could* change in ways impossible to predict. And *if* they changed in ways that leave us living more lightly on the earth, then we can assume a decreased demand for energy in general, and nuclear energy in particular. But in such a future, we *should* assume an institutional infrastructure stable enough to manage inherited sites for the storage or disposal of nuclear wastes.

In this end-point, a transformation of values in individuals drives an improvement in social relations. In the last end-point, a transformation in social relations drives improvements among individuals. Throughout the utopian literature, different thinkers place different degrees of emphasis on one or another source of salvation—social or individual transformation. During our own recent wave of utopian thinking, the 1960s, there was a lively dialogue between the politicos who marched in the streets, and the hippies who placed their faith in a contagious transformation of consciousness. This

dialectic between outside-in transformation starting with institutions, and inside-out transformation beginning with consciousness, might yet yield a synthesis that successfully combines both antitheses.

11. LIFE EXTENSION CHANGES DEMOGRAPHICS

We've already painted this future in *Tea with the Wise,* so little more need be said here, other than to note a version of the life extension scenario that differs from *Tea with the Wise,* namely, the possibility of a turn toward a very conservative politics. This possibility is based on the familiar pattern of young liberals turning into aging conservatives. Older people tend to be more cautious, less open to innovation. Would a society consisting of old codgers be so resistant to change that it would become brittle? Would a gerontocracy fail to allow enough variation to sustain creative innovation? If just one cohort of humans gained eternal tenure on the earth, allowing no replacements to crowd their space, then there would be no further opportunities for improvements on our species.

12. NEW ECONOMICS

If you read a book like Robert Heilbroner's *The Worldly Philosophers,* a history of the ideas of the world's great economists, you can't help but get the impression that economics is a soluble problem that we have not yet solved. (1) The earth has abundant resources; (2) people have needs; (3) people are willing to work at jobs that are productive and self-fulfilling. Why can't we bring these three elements together in ways that satisfy all people's wants and needs?

As Peter Drucker makes clear in his very first book, *The Concept of the Corporation,* the modern corporation is a human invention of the 20th century. There were no such institutions in prior centuries. Perhaps there will be comparable inventions in coming centuries, inventions that succeed in producing economic wealth in ways that are both equitable and ecologically sustainable. The book, *Natural Capitalism,* by Paul Hawken, Amory Lovins and Hunter Lovins, contains the blueprint for such an economy . . . and it is not so different from our own that it need be dismissed as fanciful.

An economy that works for the benefit of all would surely have the money to support institutions stable enough to manage nuclear wastes with care and prudence.

13. SCIENTIFIC REVOLUTION

Science is not likely to stand still. But scientific breakthroughs are famously difficult to anticipate. If we knew what to expect, we would have already made the breakthrough. Nonetheless, when looking ahead 500 years we have to imagine some breakthroughs as fundamental as the discoveries of electricity, evolutionary theory, quantum physics, relativity theory, or the discovery of DNA.

How might such fundamental breakthroughs change the course of everyday life? Technologies that improve productivity are bound to enhance the metabolic system in which humans relate to the earth. Both energy and material resources can be used more efficiently.

In addition to applying science and technology to the improvement of physical systems, a science of emergent systems might apply to social systems as well. Reductionistic explanations that rely on analyzing complex systems into their simplest parts are incapable of accounting for emergent phenomena like consciousness, life, language, happiness, or any number of other complex systems.

Perhaps the coming centuries will feature advances in a science of emergent systems. If so, then we would likely experience improvements in our abilities to manage such complex social challenges as education reform, health care reform, and nation building. Indeed, a breakthrough in the science of emergent systems might be the key to *A Second Reformation,* or *A Fundamental Breakthrough in Human Values,* or *A New Economics.* A social science that actually works could be the route to a better future.

14. NEW TOTALITARIANISM

Our reach for utopia could exceed our grasp. As has happened before, some bright idea about a better human future could go horribly wrong. The effort to institute some social ideal could end up with institutions that suppress human freedom in the name of that ideal. The best that can be said about a new totalitarianism is that it would probably have the means to manage nuclear wastes.

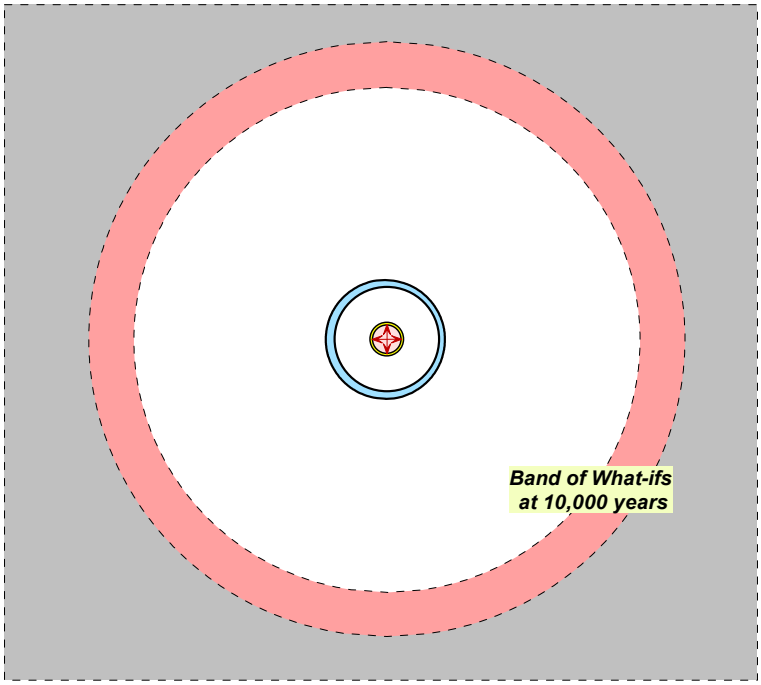
15. DARK AGES

Just as a survey of possibilities for the next 500 years would be incomplete without mention of some scenarios that are close to utopia, so the survey would also be incomplete without mention of a new Dark Ages. Any number of catastrophes could force humanity back toward a brutish existence. The very fact that regression is possible means that we cannot assume the social stability necessary to manage nuclear wastes with responsible institutional oversight.

16. SURPRISING CONTINUITY

While the previous fifteen end-points present a range of possibilities so broad that it seems inconceivable that change could cease, a thorough survey of possibilities must save a place for the perpetuation of the status quo. Stranger things have happened.

VII. 10,000-Year What-ifs



For the last step of looking out 10,000 years into the future, the scenario team was asked to brainstorm a series of one-liner, 'What If?' questions. What are some of the game-changing elements that would be at the core of different outcomes, different worlds 10,000 years in the future?

We split the scenario team into four small groups and asked each group to come up with 15-20 "What-ifs" for the 10,000-year time horizon — not full-blown scenarios, not even the briefer "end-points" we sought for the 500-year time horizon. This exercise produced four different lists with over 70 separate What-ifs.

What follows represents a summary assimilation of that process. While the original wordings have been preserved, the items have been radically re-ordered. In order to do justice to the following material, the reader should be reminded once again of the point of this exercise: Given that nuclear wastes remain radioactive beyond 10,000 years, what must we imagine in the way of possible environments that a management option must weather?

Some readers are bound to find some of the following What-ifs fanciful in the extreme. But that is precisely the point. In the follow-up to the 9/11 disaster, some accused the US intelligence apparatus of a simple failure of intelligence. Others may have been closer to the mark when they described the failure as a *failure of imagination* rather than a failure of intelligence. Given that the future is not predictable, the task at hand for the Nuclear Waste Management Organization calls for extremely imaginative probes into very distant futures.

We begin with the good news, the optimism, the almost utopian possibilities. Then we move on to a range of different downside possibilities, some man-made, some that are natural disasters. We end with the wildcards that simply didn't fit the logic of earlier clusters.

What if…

- Man evolves to a truly enlightened being closer to the Gods?
- Human evolution leads to humans with more (or less) compassion?
- We move beyond the Industrial Age, and the Information Age into a New Age?
- Multiple ages of enlightenment occur over a short time period?

What if…

- Technologies for enhancing human mental and physical performance dramatically increase?
- Humans develop a higher mind capability?
- Average IQ increases and pace of learning surges in humans?

What if we enhance our capacities for communication. What if . . .

- We can communicate thoughts without a language—ESP?
- Humankind enhances senses through genetic engineering?
- Telepathic forms of communication become a reality?

What if our emotional repertoire could change and . . .

- Humans discover 'Soma' —a substance that would produce instant happiness?
- Genetic engineering eliminates aggression (or creativity) from human nature?

What if humans become physically and spiritually integrated with ecosystems and

- Our understanding of ecological 'thresholds' leads to a revolution in our sense of the Earth's systems?
- The ozone hole is healed?
- We abandon homocentricity as a worldview?
- Human beings communicate with other species?
- Recognition of other forms of sentiency in other species leads to increasing respect and communication among species?
- The relationship between species changes profoundly?
- The human sense of morality changes?
- Humans live in a peaceful, pastoral civilization by choice…or by catastrophe?

Turning to more pragmatic means of getting there, what if a completely new economic system develops, the concept of ownership changes, and needs become satisfied by different means?

Moving now from changes in human nature and human values, what if change revolves around changes in society and culture:

What if it all comes together and . . .

- Human culture and religion become homogenous?
- Trends in technology, religion, biology and language converge?
- Science, religion, and the arts all unite in a single synthesis of knowledge?
- Global population is managed by global governance?

On the other hand, what if change is driven by divergence, societies splinter and come apart, and . . .

- Social isolation is the norm?
- We return to hunter-gatherer mode?
- We live in restricted /closed atmospheres, possibly underground?
- Religions seek autonomy by cutting communication connections?
- Ideas of nationalism and nations are obsolete, we return to city states?
- Life is 'encapsulated'; humans live in completely self-contained, self sufficient, closed loop systems—no waste is produced and legacy waste has no impact on humans?

A third variant on coming together or splitting apart: a binary split between winners and losers. What if . . .

- Society splits in two: techno-elite and techno-controlled?
- Elites harness technology and the rest are controlled by technology?

And there are further possibilities for fundamental shifts in the locus of governance. What if . . .

- Dominance of the global power structure shifts towards Africa, South America, China, India?

All of these possibilities could be foreclosed by some geological, climatological, or astrophysical catastrophe. What if . . .

- A 3,000 megaton asteroid hits?
- There has been an Ice Age?
- Major earthquakes, volcanoes, major tectonic shifts occur on both coasts?
- One in 1,000, one in 10,000 and one in 100,000 year earthquakes hit all in a single decade?
- Sea levels rise with disintegration of the Arctic/Antarctic ice sheets?
- The magnetic poles of the Earth reverse with massive disruption of hydrological cycles?
- The stratospheric ozone layer thins until the worldwide background radiation level of ultra-violet rays is ten times what it is today and the human immune system is 50% compromised?
- The rate of extinction of species accelerates and the land is thoroughly industrialized?
- Average temperature is plus or minus 10 degrees?
- Climate change makes 50% more of the Earth's land area uninhabitable?
- Humans 'freeze in the dark' because they lack sufficient energy?

If there were a natural catastrophe rendering the surface of the earth uninhabitable, at least some humans might nevertheless find a second home in the oceans or in space. What If . . .

- A change in surface conditions forces people underground and underwater?
- Humans seek adventure of space travel, colonize Mars, and interplanetary government becomes a reality?

Or our "lifeboats," too, could fail: What If . . .

- Containment of nuclear wastes breaks down and results in a major contamination?
- The human population is reduced…or humans become extinct?
- Bacteria win the war against antibiotics and infectious diseases go rampant?
- A super-virus wipes out humans, or drives symbiotic mutations?
- All knowledge of history is destroyed?

- Human minds deteriorate from pesticides and malnutrition and lose the capacity to solve problems?
- We become dwarfed and dumber because of lack of protein in our diets?

While the previous What-ifs can be arrayed along a spectrum from Good News to Very Bad News, a number of "wild card" possibilities defy easy placement in that sequence:

WILDCARDS

One cluster revolves around changes in gender and reproduction: What if . . .

- Gender differentiation is eliminated?
- Drastic changes in human mode of reproduction occur?
- The human reproductive cycle extends to 80+ years?

Another cluster speaks to the range of possibilities relating to computing: What if . . .

- Computers acquire consciousness?
- Current moves to computerization absolutely collapse?
- Life goes 'virtual'—no physicality?
- Humans can download their brains onto silicon and seek 'virtual experience' for adventure?

Others defy any easy categorization: What if . . .

- Humans can photosynthesize energy without relying on plants?
- We have an invading population of benign extraterrestrials?
- Contact is made with extraterrestrials and another species assumes dominance?
- We find a mind-blowing discovery under the ice sheet, e.g. resource discovery?
- Melting of the Antarctic ice cap reveals a previous advanced civilization on Earth?
- The distribution of species changes drastically—a new Cambrian explosion occurs?
- There really IS (or is NOT) a God—and God appears on Earth?
- Work as we know it no longer exists—in a post science, post technology world, wisdom is what is important?
- Time travel becomes a reality (both directions)?

VIII. Criteria for Testing Proposed Management Options

The focal issue for this project is:

What criteria should be applied in Canada for deciding how to manage used nuclear fuel?

In answer to that question, the following lists represent a starting point. These lists have been assembled by reordering questions raised by considering all of the 25-year scenarios, the 175-year scenarios, the 500-year end-points, and the 10,000-year what-ifs. Different scenarios and different time horizons gave rise to several different lists of questions, some provoked by the specifics of a given scenario, some by the sheer range of possibilities to be comprehended over a very long time horizon. Some of the questions are fairly general, some quite specific and detailed. For ease of consideration by readers, the several lists so generated have been reordered by topical categories rather than by scenarios or by time horizons.

Because different questions from different sources have been amalgamated under new topical headings, there is a danger of redundancy in the following lists. Some redundancies have been removed but, in the interests of thoroughness and the preservation of nuance, not all.

Once again, the main benefit of taking the trouble to consider a wide range of possible scenarios is precisely to consider *all possible* threats to any management option. Since there is no completeness proof for having thought of everything, erring on the side of length is preferable to missing something.

Environmental Implications

- How will adverse health effects and doses to maximally-exposed individuals be assessed to evaluate continued compliance over the long-term?
- Does the design protect life in general? Is it overly anthropocentric?
- Does the assessment of potential bio-hazards to living systems include modeling and calculations beyond 100,000 years?
- Would risk assessment of waste management plans under study be adversely affected by shifts in population distribution—e.g., exodus from cities?
- Is the design flexible enough to respond to changes in acceptable risk, its definition and regulations?
- Does the design rely on technological breakthroughs?
- Can the level of technology be maintained over the long term and improved as needed?
- What risks are encountered if water enters the management site? How is the degree of risk related to the quantity of water, and how might such risks be avoided or mitigated?
- What is the risk probability associated with protecting the groundwater?
- Are facilities designed for a range of external conditions—temperature, weather, and climate change?
- Can the design withstand earthquake, hurricane, nature's powerful worst?
- Does the site meet the highest standards of seismic stability?
- Is the design robust with respect to deterioration of materials?
- Does the design use materials whose properties are known for the long term—especially under high energy radiation of the containment environment?

- Does the design use materials readily obtainable and repairable?
- Does the technological design use rare metals or other limited resources that are liable to be removed from availability indefinitely?
- How would the design be monitored? Can the system be monitored?
- Is the plan flexible with respect to improvements in monitoring technology and lower levels of acceptable releases?
- Does the design facilitate corrective action when it is needed?
- If transportation is required by the management option, how will this option deal with potential risks to the environment?

Security Risks

- What is the susceptibility of the management option to various forms of interference including terrorism, crime, corruption, mischief and/or negligence?
- Does the management design guard against toxicity/exposure in a world where institutional stability is absent?
- What are the implications of security measures for surrounding communities? And what would the security measures be?
- How does the management option impact Canada's ability to develop nuclear weapons?

Financial Implications

- Has the design and operational plan fully internalized the estimated cost of future management?
- Is the design and operational plan robust through periods of economic decline?
- If the design of the management option can be altered to address a range of external conditions, what are the costs for the differing ranges of flexibility and robustness?
- Does the design and operational plan take into account additional security costs?
- Is there provision for research and development?
- Can the management plan be funded following the consequences of government subsidy withdrawal?
- Is funding for the management option dependent on continued production of nuclear energy?
- Is there a provision for third-party audit?

Public Participation in Decision-Making

- How will siting be accomplished in a way that will ensure lasting acceptance?
- How does the design and operational plan deal with risks from transportation?
- Does the proposal polarize local interests/interest groups, and if so, how would differences be resolved?
- Is a variety of concepts and methods for systematically eliciting social opinion included?
- To what extent might the public view of waste management change if wastes are from external sources that are imported to Canada?
- Does the process place high weight on the values and opinions of members of affected communities, and how are those social values to be assessed?
- What would be the effects on the management option if strife between First Nations and

Canada is high?

- Are the communities and the public involved in determining the definition of "acceptable" levels of risk, e.g., release limits and/or limits on impacts to human health and the environment?

The Management Process

- To what extent is social stability assumed by the management option?
- Is the waste actively or passively protected? Does the plan require human participation in making it less susceptible to accident or diversion?
- Throughout the long period of the management option, how are social values to be assessed and integrated into on-going planning and decision processes?
- Does the solution rely on extensive training and expert workforce?
- Is an adequate emergency response system in place if sensors reveal leakage?
- How does the plan deal with the surrounding community in the event of leakage?
- Who are the custodians and what are their standards and motivations?
- Does the plan account for human frailty/human error?
- Is there a workable, tested risk management plan that can handle different aspects of social chaos?
    - With simultaneous, multiple crises
    - With a string of cascading crises
    - A 'Multi-front war'
    - A 'Perfect storm'
- How important is knowledge-transfer to futures generations and how is it guaranteed?
- How robust is the plan to fragmentation of corporate or public sector governance?
- Does the design include a system for the full documentation of:
    - Contents at the time of placement in the system?
    - The anticipated change of contents' chemistry and radioactivity with time?
    - Essential technical information to be accessible to appropriate personnel?
    - Risk characterization over the long-term?
- Is the data accessible over the long-term?
- Does the management process continually monitor and address the challenge of long-term risk mitigation?
- Does the design provide for monitoring of the 'governance' (the management)?
- Is there provision for management system standards in on-going operation?
- Does the approach allow for key decisions to be made in the near-term and still allow for modification and further improvements?

Relationship to the future of nuclear energy/waste production?

- Can the management approach deal with long-term:
    - Different mix of fuels?
    - Ongoing import of wastes?
    - Transport across country?
    - Ongoing production of nuclear waste?
- How expandable is the solution to increasing nuclear waste imports?
- How does the management option address decentralized nuclear energy production and distribution of nuclear wastes in the future?
- Over what time period can waste enter this management option?

- To what extent does climate change and a carbon-constrained economy alter the energy mix?
- Does it make it economically or politically attractive to Canada to import nuclear waste?
- Is the design applicable to ourselves and CANDU clients?
- Are the technology, materials, and maintenance affordable and applicable to clients?

IX. Concluding Observations

In summary, the scenario team made some important discoveries in the course of its work, and reached some tentative conclusions. First the discoveries along the way, then the conclusions:

- **First,** for the purpose of imagining different worlds in which nuclear wastes might be managed, the most critical uncertainties revolve around

  1. *the magnitude of the challenge:* the size of the threat posed by spent nuclear fuel; and
  2. the degree of *socio-political-environmental well-being.*

  The first is a function of several variables, from energy demand and advances in technology to the amount and mix of spent fuel. The second affects the degree of institutional stability that can be presupposed for the ongoing monitoring and management of wastes. Using these two axes of uncertainty, the team was able to fashion four 25-year scenarios that served very effectively as wind tunnels for testing the "flight-worthiness" of proposed management approaches.

- **Second,** when the team extended the scenarios out to seven generations, or 175 years, the basic dimensions of uncertainty remained useful, but the range of uncertainty was so much greater that the four 25-year scenarios quickly splayed into twelve discrete futures, each plausible, and each challenging in its own particular way.

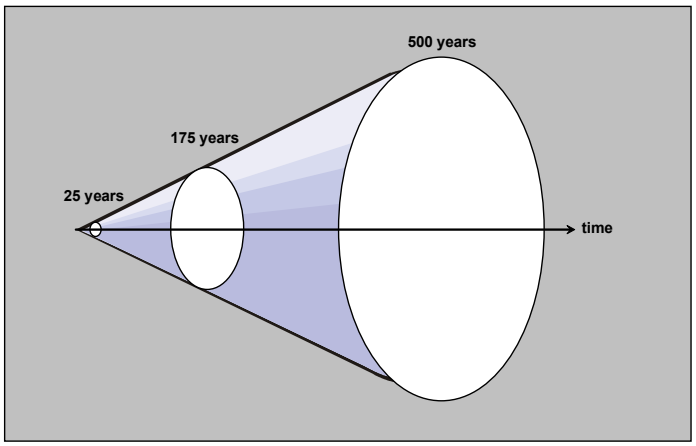
- **Third,** when the team extended its perspective from the 25-year and 175-year scenarios out to 500 and 10,000 years, the value of the exercise was qualitatively, not just quantitatively, different. The idea of building discrete scenarios, each with a narrative line extending from beginning, through middle, to end, gave way to a less structured but equally rich way of envisioning conditions. It was as if we had reached and passed a limit for applying the formal scenarios technique. Perhaps this is not surprising given the nature and rate of change over time. Consider the following thought experiment.

  > Think of the present as the apex of a cone of uncertainty widening out into the future as shown on the figure below. In this figure, the angle of uncertainty (the slope of the cone above and below the time axis) remains constant, a very conservative assumption indeed given that we know that technological advance and change over time is self-feeding and self-compounding (a more likely cone shape would thus perhaps be like the horn of a trumpet which follows an exponential curve).
  >
  > For each of the 25, 175, and 500 year time horizons, a circle of uncertainty is shown. By the time you reach seven generations (175 years) into the future, the base of the cone—the area defined by the circle of uncertainty—has grown as the square of its radius, or seven times seven: 49, almost fifty times as much uncertainty as we can imagine 25 years hence.

Now try to imagine the breadth of the cone of uncertainty 500 years (or twenty generations) into the future. Here, the area of uncertainty has grown by twenty times twenty or four-hundred times.

If you peer back into the past that far, you find yourself in a time before the nation-state, before the violin, before electricity, before telephony. How different the world will be 500 years hence after comparably life-altering inventions have been discovered and implemented!

If you try to extend this exercise in imagination to ten thousand years, or 400 generations, you will find that you lack words to name the concepts that would label the axes on which we would plot the curves to locate that unimaginably distant future. (To capture this on the cone shown below, it would have to be extended 3 ½ feet to the right and the base would rise vertically 2 ½ feet in its current orientation.) Forget about quantifying the values of variables to the second or third decimal point; we don't even know the names of the variables, much less their values, or how they will interact.



The Increasing Circle of Uncertainty.

The above thought experiment serves to emphasize how great the changes will be in the future, and how limited our ability is to predict those changes. However at the same time, it re-enforces the need to think creatively and extend our mind-sets as much as possible to prepare for those changed conditions.

Regardless of the significant limitations that confronted the Scenarios Team in its work, particularly related to the very long term, the exercise served its intended task of stretching people's thinking processes. As a result, a powerful set of questions took shape to be posed in NWMO's subsequent assessment of management approaches.

In a final exercise, the scenarios were tested in small group format against some crudely drawn management approaches that reflected the legislated requirement to consider deep geological disposal in the Canadian Shield, centralized storage above or below ground, or on site storage. In addition, the idea of reprocessing used fuel was included as part of one small group's work.

The final exercise served to bring together many of the ideas that had emerged throughout the entire scenarios exercise, not only during the formal meetings but also around the edges in informal discussion. In sum the following conclusions emerged as a result:

- **First,** that it is essential to focus as much on the management systems and the integrity and openness of ongoing decision-making processes as it is on a debate about the alternative technical methods. Only by doing so will Canadians be able to develop the trust that is needed for the management approach to be successful.

- **Second,** that the "software" of any proposed solution is as important as its "hardware." That is, institutional supports, regulatory mechanisms, and mechanisms to achieve financial surety are a critical part of any proposed solution. While there has been much debate about the alternative forms of physical containment, Parliament is a legislature first and foremost. Its product is laws. The generic institutions that we have in place are likely to be insufficient to provide an adequately robust legal framework for the long-term management of used nuclear fuel. In now moving forward, a key application of these scenarios is to test the current and potential regulatory regimes to identify issues and better understand strengths and limitations.

- **Third,** that it would be useful for others to engage in a similar process in order to assess the dimensions of the challenges involved in managing spent nuclear fuel. Scenarios provide a very broad tent under which widely different perspectives can gain a fair and respectful hearing. Because the management of nuclear wastes is not just a technical problem, but a social and political and ethical problem, it is crucial for Canada to face the problem by employing a transparent and inclusive process.

- **Fourth,** that the development of alternative scenarios by a diverse team of concerned individuals, rather than reliance on an expert forecast, had provided a valuable method for addressing the problem.

Lastly, in the course of this final exercise, some interesting preliminary observations arose that are important to report.

- There was little disagreement, if any, with the current practice of storing used nuclear fuel on site until the main heat-generation and initial radioactivity-reduction phase has passed. (Thus all 25 year scenarios accept on-site storage as logical. Some of the older wastes, now 45 years old, will soon be ready for more permanent placement, if that is desired, but this takes us beyond 25 years.)

- Discussion of on-site storage led to a sense for some that while the idea of this method may look like a default do-nothing option, it is neither as dangerous as some might fear, nor as permanently viable as others might hope.

- No major technical or managerial advantage was identified associated with centralized storage.

- The idea of ensuring retrievability of the used fuel for the foreseeable future was championed by many in the group. However, the idea that the design of any facility should include a mechanism to quickly and relatively easily transform the condition to a state of permanent disposal (for example faced with the threat of terrorism or social collapse) also enjoyed support.

- Discussion of the implications of terrorism – obviously much heightened since the attack on the World Trade Centre – led to a sense expressed by some that the only safe way to guard against the range of possible threats to surface storage would be to opt for a very deep form of repository.

- More generally, for 175 years and beyond, deep geological emplacement reduced certain risks arising from the conditions described in many of the scenarios more effectively than extended surface storage. However, a rigorous comparative analysis was not completed.

- A number of participants expressed the view that some period of on-site storage followed by placement in a deep repository seemed to be the best combination of approaches.

- In some participants' eyes, a willingness to support any management approach is closely tied to whether or not the used fuel issue is bounded either by a commitment to end the production of further used nuclear fuel, or by some other means. This issue remains to be examined in detail.

- The question of how far into the future the responsibility of the current generation should extend was raised a number of times. Considerable support was voiced for the idea of a "rolling" seven-generation perspective. That is, each generation should design within a seven generation time frame. Any succeeding generation would thus have six generations to learn from and if necessary adjust the decisions made by the previous.

- There was a general sense that as compelling the methodology and as convergent as the above conclusions and observations, the scenarios work is not yet complete in terms of the value that it has to add to the NWMO process. Several members of the team called for a further iteration of both the scenarios and the criteria for the testing of any proposed management options. Others pointed out the need to produce a concise summary of this exercise in a form that could be broadly used as a foundation for scenarios deliberations by others.

Appendix

Interview Report for the NWMO Scenario Process

Reporter: **Nicole Boyer, GBN**

Overview

It's hard to think of another issue so complex along so many dimensions (i.e. the social, political, ecological, ethical, scientific and technical) and thus riddled with so many intractable dilemmas and tradeoffs as finding an equitable and enduring solution to the management of used nuclear fuel. "There is a reason why no one has solved this problem of nuclear waste," one person concludes. "It's because it's so darn hard!" Fortunately, scenario planning is one of the few techniques we have at our disposal with the potential to help crack this seemingly impossible problem.

With this aspiration in mind, Global Business Network (GBN) was commissioned by the Nuclear Waste Management Organization (NWMO) to facilitate a scenario planning process to get better traction on this long-standing issue. Specifically, this process is intended to contribute to developing the "wind-tunnel" in which to test various options.

The first step of the process was to interview over 20 participants from May 2003 to July 2003. The interviewees/participants were chosen by the NWMO for their diversity in views and backgrounds, their knowledge domains, past experience with this issue, and stakeholder interests.

The purpose of these interviews was to learn about the key strategic issues around spent nuclear fuel in Canada, but it was also aimed at understanding people's "mental maps"—those conscious and unconscious perspectives, perceptions, assumptions and worldviews that shape the ways we see the future, and thus the choices we make in the present. Surfacing these mental maps is especially important in the case of used nuclear fuel. The debate is strongly influenced, and often stymied, by conflicting worldviews and perceptions, so this kind of deeper understanding is critical if the conversation is to move forward.

The content of this report is thus an analysis and synthesis of what we learned in these interviews. It falls into three parts. **Part I, Process is Key,** addresses the number one theme resounding throughout the interviews. Since we are in the early days of this engagement, with time for reflection and iteration, these process thoughts may inform the design of future pieces in this overall endeavor. **Part II, Framing the Questions for the Future,** zooms up to the big picture and summarizes how people perceive the major uncertainties and questions for the future. These are the building blocks of good scenarios, so this represents the bulk of people's discussion. **Part III, Framing the Solutions,** then talks about how people are approaching the various options on the table—together with some early thoughts on some emerging criteria for a robust policy approach.

While all interviews were conducted in confidence by GBN, we have quoted freely using people's own words but without attribution.

I: Process is Key

There was one unanimous and resounding point of consensus in all of the interviews and this had to do with the *process*. Everyone stressed that a successful outcome depended on the perceived integrity, independence, and transparency of this process. To that end, "the process must engage the full spectrum of views," and include, "a much broader dialogue with the public." As someone put it, "we have to make people in society at large *experience* being represented in the conversation about this problem." Engaging different cultures and parts of society, as we are doing in this process, "is part of the solution itself," he added. The process is so critical, other people emphasized, "because we need to build trust." "Trust has been eroded so badly over the past few years that this is not a trivial undertaking."

> "The use of studies to prevent action is a famous government activity," quipped one participant. So this process "has to make a difference." This input must be "channeled positively into motion and action." A good outcome should "focus on developing common ground" and a shared context for the future. "We need to figure out how to talk to each other without defensiveness and taking sides." Most people were cautiously optimistic that it would result in something constructive, but at the same time reserved the right to be skeptical given the difficulty of the problem and the lackluster attempts in the past to address it. The last environmental assessment, for instance, took almost 10 years and resulted in "deadlock." People were polarized in their views. "Ideological baggage and vested interests got in the way."

A negative outcome, then, would be a repeat of this situation, which may be why one participant worried about triggering a national debate on the future of nuclear waste. "If we get so entangled in these big picture issues around nuclear in general, we might be back to square one, paralysis… Meanwhile, the nuclear waste keeps growing, piling up, waiting for a solution."

Specific process concerns were also raised. One person was worried that the process would "avoid some of the tough conversations," because we would stay at too high of a level in the scenario work. Another participant also mentioned a "sacred cow" about the mandate of the Federal regulator, key assumptions which may prejudice the solution. For instance, the solutions in the R-104 report state that they should not depend on social institutions to ensure safety for the future.

This may have good intentions, but it puts certain biases on the approach taken, "favoring perhaps a passive geological solution." In a similar vein, another participant feared that we were only looking at a limited number of options. "The mandate says free thinking and then defines a small bracket." We will need time for "acts of imagination" to emerge around the solutions. Some people felt that vested interests would undermine the quality of thinking. As one person plainly put it, "the owners [of nuclear waste] have a strong interest in finding a solution, but not necessarily a 50-year solution, let alone a 10,000-year solution! They would rather get it off their plate and out of the way." Under these conditions, this person doubted whether an intelligent, thoughtful, and robust decision could be made.

II: Framing the Questions for the Future: Key Uncertainties and Challenges

Good thinking about the future often starts with finding the right questions to ask. So we probed people for their views about the various challenges, uncertainties and strategic issues that might influence the future of used nuclear fuel. Since the scenario process is looking across multiple time frames (25, 175, 500, and 10,000 years ahead), people were asked to stretch their thinking along

these temporal scales. It's hardly surprising, then, that people foresaw a wide range of challenges, which we clustered into themes, ranging from very broad uncertainties concerning the future of the planet, our species and civilization, to more concrete and strategic challenges facing the nuclear energy industry and waste disposal. In illuminating these **eleven challenges**, we will start with the bigger picture questions and issues, and then drill down into the more immediate questions for nuclear waste. Of course, these challenges are not discrete but highly interdependent, so this list is just a list of convenience. Think of these challenges as nested in a set of interlocking and overlapping circles, in a three-dimensional Venn diagram if you will, to get a more realistic picture of their proper relationships with one another.

Challenge #1: Limitations of Our Thinking & Mindset

At the highest level of abstraction, there is a profound epistemological challenge facing us: that is, a challenge in our very capacity to know about the long-term future. How do we – as a species and as a society – develop this Long View wisely and rigorously? From a cognitive/biological perspective, are we physically capable of thinking this far ahead? From a social perspective, is this possible? Most people were understandably intimidated by this challenge. One participant underscored the enormity of our task by putting it this way: "There are no nice pat case histories where civilizations have had to think ahead for this length of time. This actually *is* an unprecedented, complicated issue—an endeavor that extends well beyond just the nuclear issue." Other people were downright skeptical. "We are clearly limited by our mindsets. Just as 175 years ago, our present was unimaginable, the next 175 years will be equally as hard to fathom."

Even Stewart Brand, one of GBN's founders, the author of *The Clock of the Long Now: Time and Responsibility* (1999), and thus perhaps *the* person who has spent the most time thinking about how to think ahead 10,000 years, questioned our ability to accomplish the task. "There is a pathology of trying to manage perfection, and trying to manage it over millennia." Brand also questioned the utility of stretching this far: "Perhaps thinking this far into the future is a mistake in the case of nuclear waste? If this is about making things happen, perhaps that should be the focus in the design problem."

Despite these challenges, most people felt that this kind of thinking was essential, even inspirational in its attempt. "We shouldn't be dispirited about these challenges," said one of the group's elders. "We need to engender hope by doing this."

Challenge #2: Homo Sapiens vs. Mother Earth – Adaptation or Annihilation?

Quite a few people talked about how, if human beings are to have a long-term future, we will need a "profound shift of our worldview and cultural assumptions about our relationship to natural systems." To this point, one participant cautioned that there were some embedded, anthropomorphic assumptions about this NWMO project. He phrased it this way: "is our responsibility in this project to the people over the planet, including other species and its natural systems?"

> One contingent of participants expressed strong concern about humanity's ability to survive collapse and self-annihilation. People mostly talked about this rationally and in measured tones, as if telling a well-understood history. "The Industrial Age logic run amok for the past 100 years, polluting and destroying our physical environment, perhaps irrevocably," said one. And while danger of humanity's collapse seemed far off for some, the perceived urgency was more short-term focused for others. "Learning how to live on the planet without destroying it is something we need to figure out in the next 50 years, not 500. "This is possible because in Canada we have seen this happen with our forests,

with climate change in the Artic, and in our mining communities." "We used to think this was just the price of making profit, for economic growth," argued one person. "But now we are seeing that these assumptions about growth were false. That without the healthy services provided by Mother Nature, we don't have much to rest on."

Many people speculated that climate change, or other large-scale ecological events, might drive a wave of cultural change and adaptation. The more hopeful of the group felt that it was possible to see a future where "we redefine our relationship with our natural systems that is more integrated and holistic – something much closer to how First Nations and other indigenous cultures view nature." This redefinition might include re-perceiving "how we see waste." In nature, there is no such thing as waste. Waste is either food for others or nutrients for other services. So if this shift in worldview happened, we would see cradle-to-cradle industrial systems and full life-cycle costs internalized into prices. Related to this conversation, deeper shifts in the nature of humanity would also emerge like, "the rise of the Wisdom Society, where values like humility and modesty overshadow our current preoccupations with materialism and consumption."

Within the group, there was a "realist" camp. This group, while not discounting an apocalyptic view of the future, saw this scale of change much slower in coming. This view also didn't think a better future was dependent on a major shift in values. "It would help, that's for sure, but it's not necessary," said one person. A number of other factors are more likely to change behavior and attitudes, such as technological breakthroughs (#10), new economic incentive structures and a better energy mix (#11), or new risk management tools (#5).

All of these views were more complementary than divergent from each other, however. When thinking at this level, there was far more agreement in the nature of the problem than not.

Challenge #3: Stability of the Future

Strongly linked to the challenge of thinking about the very long term is the impossibility of knowing just how stable the future will be. Population trends, immigration patterns, climate change, social cohesion, the evolution of civil society, and the impact of religion – the list of drivers that may impact the stability or "governability" of society is long. And while many people, on a visceral level, believe in the inevitability of a doom-and-gloom scenario, most acknowledged that we just can't know if the future will turn out this way or not.

Challenge #4: Long term Guardianship and Responsibility

Given the challenges thus far, how are social institutions and human ingenuity going to adapt? If we encounter future large-scale shocks, what are the implications for how we govern? How are power structures going to evolve? What will civil society look like?

These questions are grounded in concerns about the here and now, not just for the distant future. Current models of governance are perceived to be failing society or performing sub-optimally. All of the incentive systems – best articulated as the NIMBY and NIMTO (Not in My Term of Office) syndromes —make it systematically and culturally impossible to tackle long-term issues. "Which Minister will have the guts to take an unpopular decision, spending millions of dollars, to benefit people who are not yet born?" asks one person rhetorically. The inability of governments to act wisely and rationally, with intergenerational equity in mind, was perceived to be a major constraint for the future. Yet, at the same time, people argued that the imperatives to develop these new forms of governance have never been greater. "We can no longer afford this high discount rate for the

future," said one person. The price for deferring these issues is becoming observable and measurable in our lifetimes. "The story of the cod fishery, with its recent permanent closure, is a case in point. Finding a sustainable path much sooner would have saved the fishery and the communities that it supports."

In the case of nuclear waste, the specific questions include:

- **"Who should be responsible? Should this be a collective issue or an institutional one?"** The current polluter-pay approach is not the total answer, mused one person. "But making *everyone* responsible is also very hard, requiring one of those values shifts." Is this the best solution for ensuring the long-term stewardship of this waste? Perhaps. Other cultures have done this over millennia with shared resources. "But can we learn how to do this in time?"

- **How do we develop long-lived institutions or other mechanisms that ensure the safety of the environment and humans?** Again, this question touches the present, more than people realize, and pertains to how regulatory frameworks are being developed today. "Very few legal institutions have lasted more than 50 years," said one participant. "In the context of nuclear waste, we will have to be very creative in thinking about how to create this kind of soft infrastructure."

Challenge #5: Creating the Tools for Managing Unconventional Risk

Throughout human history, we have invented all kinds of practical and conceptual tools to help us manage and assess risk in the future. But assessing risk becomes tricky the farther out you look. "Statistical projections don't work very well in determining risk," argued one person. "We need to make judgments about the future, not just projections." The difficulty in risk assessment only increases in magnitude when it comes to really complex issues like nuclear waste. "The science is so far beyond the average Joe in the street, and even the engineers who design these things don't really understand all the variables, that risk can't be independently and accurately assessed." A more positive future, one where we can adapt successfully with new social and political ingenuity, will start with rethinking our tools for risk.

(Footnote: For an excellent summary of risk assessment dilemmas, with specific mention of the nuclear industry, see "RISK: The Art and the Science of Choice" by Denise Caruso, The Hybrid Vigor Institute (2002): http://hybridvigor.net/health/pubs/HVrisk.pdf)

How science is conducted, as we will consider next, is a big part of this revolution in risk assessment.

Challenge #6: Scientific Knowledge Versus Public Opinion & Values

If C. P. Snow were alive today, he might be surprised to see the Two Cultures still battling it out. The ongoing tension between science and technical expertise on the one had, and public opinion and values on the other, was a recurring theme in the interviews. Knowledgeable experts worried that, "we can't have a fact-based conversation" about nuclear energy. With low public awareness of the issues, they complained about how the public was "overly emotional," "fearful," "irrational," and "ill-informed." On the other side of the divide, we have other stakeholders complaining about the arrogance of experts. "The scientists and technocrats act like Gods," stated one person, which was scary because history has shown just how often the experts get things wrong. As another individual pointed out, "we can't say this is *just* a technical issue and that we will solve it later. We said that 40 years ago, and look were we are today."

Having highlighted this cleavage between expert knowledge and public opinion, most people had a more balanced view of this debate. "The big questions [around nuclear waste] are social and political, not technical," said one person and these sentiments were repeated throughout the conversations. "The science is very interesting, but asking the question – Is this really good for humanity? – is much harder, and where we need to focus." This view, which tries to include both perspectives, is also grounded in public opinion research, which shows that people "come to judgment" on important issues through the lens of their values and emotions first and foremost, with facts and rational arguments playing a secondary role. See *Coming to Judgment: Making Democracy Work in A Complex World* (1991) and *The Magic of Dialogue* (2001) by Dan Yankelovich.

Consulting the public is thus essential in getting anything meaningful done in good policymaking. This is especially true for nuclear energy and waste. As one participant phrased it, "Canadians didn't choose nuclear energy when it was first developed…. Nobody asked me!" In the future, with more transparency and opportunities for input, governments may not be able to get away with this kind of top-down decision-making. Instead, the focus might shift from blaming the public for being "irrational" to "understanding more deeply where their fears come from." In any event, the perception of the public around nuclear energy in Canada will be "an important driving force in its own right," which is why people were so concerned with the process of this NWMO mandate. Get this piece wrong and chances for getting things right are seriously hampered.

Challenge #7: The Complexity of Nuclear Energy Science

"There are still many pieces about nuclear science and waste that we don't understand," said one participant. For instance, one of the lessons from past studies was "the incredibly complex inter-relationship between biological, statistical, geological, metallurgical and other information each dependent and connected to the others." He also confessed that they lacked expertise "on social, human and psychological dimensions, which were needed to create a complex, holistic picture of the system."

The complexity of nuclear science may either be increased or simplified by new knowledge coming from other domains of science like nanotechnology and biotechnology. For instance, we may learn whether or not radioactive waste is really harmful for 10,000 years. "Perhaps we will learn that it decays faster than that?" asked one person hopefully. "Perhaps these projections are not really accurate."

Challenge #8: Geopolitical Complexity, Global and Local Dimensions

Policies about nuclear energy and waste are also complicated by the fact that this is a global issue as well as a Canadian issue. While there may be a diversity of approaches to nuclear energy and waste disposal, given the nature of the problem, "the policies of one jurisdiction regarding nuclear waste will have direct and indirect implications for Canada's policy." Many participants wanted to learn more about how other jurisdictions – France, Germany, Japan, and the UK – were handling their dilemmas. But the country people worried the most about was our "power-hungry (pun?) neighbor to the South, the United States." How the Americans choose to approach nuclear energy and waste will impact Canada's policies in obvious and surprising ways, therefore these were scenarios we needed to think about and rehearse.

Challenge #9: The Question of Long-term Safety

"Can nuclear energy and waste be made safe over the long term? Is this technically and socially possible?" This challenge is of course a subset of almost all of the others. From a technical perspective, we are still fallible. As one person reminds us, "lots of things are designed *not* to fail – say the O-rings or the external heat shield panels on the Shuttle – and they still do." Even people who believed there was a technical solution to nuclear waste felt that it wouldn't matter that much. The danger will still exist, because, "there is no solution to the proliferation problem." That genie is out of the bottle. Nuclear waste is always going to be, "a target for evil and untoward forces in society." Transporting nuclear waste, which countries like Japan need to do, only compounds the risk profile, especially in an increasingly unstable world.

"Will there be another catalyzing event in the future – like another Chernobyl or terrorist attack using a 'dirty' nuclear bomb–which makes nuclear power socially and politically unacceptable?" Even without these events, given these uncertainties, "can we imagine a world where nuclear energy is *ever* publicly acceptable?"

Challenge #10: Towards a Technological Breakthrough

The rules of the game for the nuclear energy industry could be rewritten by a technological breakthrough. For starters, better recycling "closed loop" technologies would make a difference. But the Holy Grail would be a revolutionary step-change in technology: the potential for transmutation. "Transmutation is simply a process where the bulk of radioactive isotopes are turned into stable products," explained one person. The best-case scenario in many people's minds would be to develop a technique that was in keeping with nature, or "biomimetic." (For instance, one person hoped, rather playfully, that this would be something simple like the use of limejuice.) Some believe these breakthroughs are foreseeable in the next 20 to 50 years, especially with the convergence of nanotechnology and biotechnology. Under these conditions, nuclear waste might be re-perceived as a resource that we "mine" from storage sites. In this case, "having the waste relatively accessible would be the preferred option." The major uncertainty is how long will this R&D take before it bears fruit? And at what cost? Society may say that this investment is not worth the cost, given other alternatives to spending the money. Or society might not be in good enough shape to even make that assessment.

Challenge #11: The Future Energy Mix

Last but certainly not least, the future of energy was top-of-mind for almost everyone. Most people wanted to know, "what the energy mix of the future would look like." "Within this mix, how much will be nuclear and for how long, another 50 or 500 years?" "When will alternatives to hydrocarbons come online?" Others thought about the migration path from fossil fuels to a hydrogen economy. Some people posited that part of this migration or transition to hydrogen might drive a renewed interest in nuclear power. "Conservation alone", they argue, "won't achieve sustainable energy consumption patterns." "Even hydrogen is going to need an energy source." In any event, people were most anxious to now how the "economics of energy production – and in particular electricity generation – change over time." "Will there be some big breakthroughs or not?"

Many of these questions are obviously linked to other external factors as well. For instance, "how much energy will the planet need" to survive and thrive? Who will be consuming this energy and, "how will different parts of the world, say the developing and developed, differ in these consumption patterns?" These questions, in turn, will be affected by drivers like climate change, population trends, shifts in values and political choices, and technology, all of which might shift the paradigm

shaping how we think about energy generation and consumption. For instance, if we evolve away from this industrial age logic, we might have different ideas about growth. “Right now there is an assumption that we need energy to grow economically and thus for wealth and prosperity. What if that changes?”

III: Framing the Solutions

As we have seen from these 11 challenges, decisions about used nuclear waste are dependent on many issues. This hasn’t stopped people from talking about the various solutions to these issues. And while the remit for the scenario process is to help construct the “wind-tunnel” in which to test future solutions as objectively as possible, at the end of the day, this process will be about making informed judgments amidst many unknowable factors and uncertainties. Given that, it’s useful to see how people are framing these solutions as a baseline for future conversation. For instance, it’s useful to step back and ask, to what extent is our language about these solution spaces biasing us or blinding us to other options? While the summary below is incomplete and will be missing a great deal of detail, it does reveal some core strategic dilemmas, which the scenario process must address.

While some interviewees could be classified as “techno-optimists,” others could be described as “social pessimists.” Many people talked about these worldviews, which participants saw as shaping how one frames the optimal solutions to the management of used nuclear fuel. While this is obviously a simplification—and more of a continuous spectrum than a hard and fast distinction—techno-optimists are more likely to believe transmutation is the answer on the horizon, while social pessimists are uncomfortable with any solution that relies too much on technology.

Among the various approaches to the management of spent wastes, three were mentioned most often:

1. Irretrievable deep geological disposal in the Canadian Shield or elsewhere.

This was the original solution, agreed upon by the technical and scientific experts in the last government study over ten years ago. But after a protracted environmental assessment process, this approach was later challenged because it didn’t reflect “social and public opinion” factors. Deep geological disposal, however, does seem to be the route the US is taking with its proposed site at Yucca Mountain in Nevada.

People who oppose this solution argue that there is no guarantee that the containers won’t leak or break down over time, “that we simply don’t know enough to go this route.” “It’s also irreversible.” Once the waste is down there, it will be almost impossible to retrieve safely, so this is the least flexible of options. Further, there is also the problem of intergenerational communication: how do we let people in the distant future know not to mess with the waste, that it’s harmful? Is it better not to have any sign? (Because the curious will be made only more curious by such a thing.) Or should we think hard about disseminating this knowledge in a way that lasts millennia?

2. Status Quo Solution: Containment is Enough

This view argues that storing the waste as we do now, in “ ‘swimming pools’, is safe enough and cost effective. It could be made safer, however. So spending R&D money on this is where attention should focus.”

Not being able to guarantee the security and long-term safety of these containment sites was seen as the main reason against this option. Within a post September 11th world, strong and vivid fears exist

about future acts of terrorism and geopolitical instability. "Reality could plausibly resemble a Tom Clancy novel, with terrorists breaking into Canadian sites" (Russia is just on other side of the Pole) and re-purposing nuclear waste to make "dirty bombs."

3. Defer Long Term Solutions Until Breakthroughs

This school of thought argues that we should defer any irreversible long-term solution until the science and technology evolves to a point where reprocessing or transmutation of the used nuclear waste becomes possible.

The trouble with this is that it presupposes some measure of stability in society and institutions, and that a technological breakthrough is possible and worth waiting for.

This option also triggers a vexing short-term versus long-term dilemma for making a policy decision around nuclear waste**.** As one participant phrased it: "if a 'good' solution, given today's knowledge, stops working after 20 years, then this may cause more harm and damage in the long term. Whereas something that is seen to be a 'bad' solution today, like using swimming pools, might actually have fewer bad outcomes from the long-term perspective." The trouble is, given all of the uncertainties surrounding used nuclear fuel, how do we resolve this dilemma?

To be Nuclear or Not, Is That the Question?

Underneath these debates about used nuclear fuel, the broader question about the future of nuclear power in Canada inevitably popped up. "Will it continue to be part of our energy mix? Should it be?" As one participant thoughtfully asked, "is it possible to work on a solution to nuclear waste without an answer to the question of whether the nuclear industry will be shut down or not?" In practice, most people couldn't separate these questions. If you talked about the future of nuclear waste, one needed to talk about the future of nuclear energy. Having said that, a few people felt that, pragmatically speaking, it was necessary to do so because regardless of what happens with nuclear energy in Canada, "we are still going to have the waste to deal with."

Not surprisingly, the strongest points of disagreement were around these questions, and the future of nuclear energy in general. While these interviews are clearly qualitative and non-scientific, a fair number of the people interviewed were strongly or moderately opposed to continuing with nuclear energy generation in Canada. "A good scenario would be the full phase out of nuclear power," said one person. "Nuclear energy was a good idea whose time has passed," said another. It's now time to understand our "exit strategy" for nuclear; that is, the implications in terms of energy flows and reduction in capacity, and in terms of loss of employment in certain provinces.

Most participants, however, tried to remain agnostic, or at least felt that it was unhelpful to paint nuclear power as either a good or bad thing. As one participant put it, "Nuclear is not a yes or no. We are involved in a long-term experiment with the current plants, where we can see if society is capable of running them safely, dismantling them if appropriate, with sufficient political stability over time."

The pro-nuclear view argues that not only is nuclear power good for the economy, it offers other benefits as being a "cleaner" energy solution and something that can help Canada meet its Kyoto protocol commitments. Nuclear advocates believe we should build more plants, not shut them down. The problem is more about figuring out how to "re-brand" nuclear as a positive option, and helping the public – who are too emotional and ill informed about this technical issue – "get it."

Some people felt that the market should decide the future of nuclear as an energy source, and that this would have a good outcome for society. "If you internalize the full cost of nuclear, the industry goes away." "Current energy prices are distorted by huge public subsidies, some direct and obvious, others more indirect and concealed," stated one person. For instance, the government provides the nuclear industry liability insurance. If something went wrong, the public taxpayer would absorb the risk, not the industry. "If this law went away, no one would give the nuclear industry any money."

Framing the Criteria for a Future Approach

As people discussed the various options or solutions for used nuclear waste, a number of high-level criteria emerged, which may have a bearing on future conversations.

These criteria included an approach that "avoids negative and unintended consequences," or an outcome that is the "least bad option." More positively, the solution space for addressing used nuclear waste must "provide more options, not less, for the future."

Whatever approach is chosen, it should be flexible, be stable enough to last well into the future, and be able to learn and evolve as conditions change. As much attention should be spent on designing a future-oriented learning process as is spent on the technical solutions. We should look at other industries, "like tobacco and asbestos, to see what we can learn."

Responsibility for dealing with these solutions would ideally be shared between the private and public sector, with well-aligned incentive structures encouraging efficiency and sustainable practices. Science would play a strong role, but the conversation must acknowledge the role of values and public opinion.

Regardless of what the criteria or solutions may be, there was a strong hunger for new and creative ideas – options currently not on the table.