Canadian and USA Low-Level Radioactive Waste Disposition: A for Comparison for Consolidated Benefits

Written by:
Glen A. Rae, VP Canada & Mexico, Energy*Solutions*
Bud Arrowsmith, Senior VP Energy*Solutions*
Dr. Neil Alexander, Consultant, Bucephalus, Inc.

Abstract

An overview is provided of the history of USA waste disposition relative to changes in both the environment and the waste-management industry marketplace. It details present handling, processing, and disposition technologies, showing current conditions and options, as well as anticipated changes that will respond to market conditions. Challenges facing generators and disposal companies in the USA are identified, and actions are addressed. Finally, lessons learned and current technologies are applied the challenges facing Canadian radioactive waste generators in order to demonstrate benefits to the Canadian waste-management market.

Introduction

The Canadian and USA approaches to the management of radioactive wastes produced by the nuclear stations were originally very different. In Canada, the producer managed and stored their own wastes at their own facility, while in the United States, wastes were shipped off site for disposal in private or state-run disposal facilities.

Originally the USA had six available disposal sites, but over time this has been reduced to three, with only one being seen as being available for the nation’s long-term use.

Disposal prices have increased dramatically reflecting market economics, changes in regulations and technology development and this has led to a vibrant industry based on innovation that includes generators, commercial processors and disposal site operators.

This innovation has reduced the volumes of the more challenging wastes going for disposal and reduced the prices of the less challenging wastes. Overall the price paid by the stations for disposal has dramatically reduced. Canada has not historically benefited from these processing opportunities but recent changes are now making this possible.

This paper provides an overview of the history of USA waste disposition relative to changes in both the environment and the waste-management industry marketplace. It details present handling, processing, and disposition technologies, showing current conditions and options, as well as anticipated changes that will respond to market conditions. Challenges facing generators and disposal companies in the USA are identified, and actions are addressed. Finally, lessons learned and current technologies are applied to the challenges facing Canadian radioactive waste generators in order to demonstrate benefits to the Canadian waste-management market.

Low-Level Waste Definition

The USA term “low-level radioactive waste” or “LLW” has carried a changing meaning over the years. When the U.S. Nuclear Regulatory Commission (NRC or the Commission) initially promulgated the LLW disposal regulations found at Title 10, Part 61, “ Licensing Requirements for Land Disposal of Radioactive Waste,” of the *Code of Federal Regulations* (10 CFR Part 61), the term LLW was exclusionary. It generally meant that portion of the radioactive waste stream that did not fit the prevailing definition of high-level radioactive waste (HLW) or intermediate-level radioactive waste, with concentrations of transuranic (TRU) elements less than 100 nanoCuries per gram (nCi/g).

Some LLW has radioactive material concentrations comparable to that of spent nuclear fuel (SNF), and the NRC considers this waste to be greater-than-Class C (GTCC) LLW. The U.S. Department of Energy (DOE) is responsible for managing such wastes.

LLW is currently defined in 10 CFR Part 61 the same way that it is defined in the Low-Level Waste Policy Act of 1980 (LLWPA) and the Nuclear Waste Policy Act of 1982, as amended—specifically, radioactive waste that is not classified as HLW, TRU waste, SNF, or byproduct material as defined in Section 11e.(2) of the Atomic Energy Act of 1954 (AEA – i.e., uranium or thorium tailings and waste).

LLW covers a wide range of items including

- Contaminated protective shoe covers and clothing
- Reactor water treatment residues
- Equipment and tools
- Needles and syringes
- Laboratory animal carcasses
- Highly irradiated reactor components.

The radioactive material concentration can range from just above background levels found in nature to, in certain cases, very high concentrations of radioactive material, resulting from parts from the inside of a nuclear power plant reactor vessel.

The NRC classifies commercial LLW as Class A, B, or C (see Table 1). Key decision parameters in this classification system are the physical stability of the waste form and packaging and its radioisotopic concentration.

Table 1
Overview of 10 CFR Part 61 LLW Classes and Waste Characteristics

Class	Radionuclide Concentration	Waste Form	Examples	Intruder Protection*	Waste Segregation
A	Low concentrations	Minimum waste form requirements No stabilization requirements	Contaminated protective clothing, paper, trash	No measures to protect intruder Waste decays to acceptable levels to intruder after 100 yr	Unstable Class A waste must be segregated from Class B and C wastes
B	Higher concentrations Activity generally 10 – 40 times greater than Class A	Minimum waste form Requirements 300-yr stabilization requirement	Resins and filters from nuclear power plants, wastes encapsulated or stabilized in concrete	Requires stabilization of waste form to protect intruder Waste decays to acceptable levels to intruder after 100 yr, provided that waste form is recognizable	Need not be segregated from Class C wastes
C	Highest concentrations Activity generally 10 – 100 times greater than Class B	Minimum waste form requirements 300-yr stabilization requirement	Nuclear power plant reactor components, sealed sources, high activity industrial waste	Requires stabilization of waste form and deeper disposal (or barriers) to protect intruder Waste decays to acceptable levels to intruder after 500 yr	Need not be segregated from Class B wastes

* The 10 CFR Part 61 regulation assumes a 100-yr caretaker period.

With disposal capabilities available, the US NRC has historically discouraged the use of on-site storage. In addition, USA accounting regulations require companies to account for the costs of waste in the fiscal year it is generated. This prevents a generator from deferring costs by storing waste. These policies promote the real time disposal of waste generated.

USA Disposal History

In 1971, a total of six shallow-land-burial (SLB) LLW disposal facilities were licensed and operated to dispose of the USA commercial LLW (see Table 2). Most of these facilities were located within the boundaries of or adjacent to a much larger Federal reservation operated by the Atomic Energy Commission (AEC). Four of the disposal sites — Beatty, Barnwell, Maxey Flats, and West Valley — were licensed by their respective host states through the Agreement State program with the AEC. The AEC licensed the two remaining sites (Richland and Sheffield) because Washington and Illinois had not become Agreement States at the time of licensing.

Table 2

Site	Operational Period	Original Licensing Authority (year)	Status	Comments
Beatty Nevada	1962–1992	AEC (1962)	Closed	A site adjacent to the now-closed LLW disposal facility is currently operated as a RCRA- and PCB-approved disposal facility.
Maxey Flats Kentucky	1963–1977	State (1962)	Closed	Designated as an EPA Superfund site in 1986. Remediation completed in 1991.
West Valley New York	1963–1975	State (1963)	Closed	LLW operations ceased in 1975 when burial caps leaked contaminated water.
Richland Washington	1965–present	AEC (1965)	Open	Co-located within the Hanford nuclear reservation. Disposal site leased from the Government. Disposal for NW Compact,
Barnwell South Carolina	1969–present	State (1971)	Open	Originally licensed for above-ground LLW storage. In 1971 LLW burial was approved. Open to all USA until July1, 2008 when it will operate for the Mid-Atlantic Compact only.
Sheffield Illinois	1968–1978	AEC (1967)	Closed	Attempts to expand disposal capacity in 1975 were unsuccessful because contaminated leachate was detecte effectively ending site operations. In 1988, the Sheffield operator agreed to a 10-year monitoring plan with the state.
Clive Utah	1991–present	State (1991)	Open	Initially approved as a DOE uranium mill tailings disposal site. Subsequent license amendments were received for the disposal of naturally occurring radioactive material (NORM – 1987), LAW (1991), mixed LLW (1993), AEA Section 11e.(2) materials h (1994), and Part 61 Class A LLW (2000).

The commercially operated sites adopted the practice of near-surface, SLB disposal technology adhered to at existing AEC facilities at the time. This disposal method relied on relatively simple engineering designs to isolate wastes from infiltrating groundwater. The natural (geologic) characteristics of the site are the principal attenuators of any radioactive material that might be released to the accessible environment. There were no systematic site selection criteria or design requirements that could be used to establish the best mix of features necessary to contain and isolate the wastes. Disposal generally involved clearing and grading the land and excavating shallow unlined trenches – generally less than 50-feet (15-m) deep – that would be used to receive the waste.

At the time, no specific packaging requirements existed for LLW disposal. LLW was packaged in a variety of container types that were randomly dumped or stacked into the trenches. The waste was generally placed into the trenches on a first-come, first-served basis. Trenches were then backfilled using materials removed during trench excavation, compacted, and graded to create an earthen mound cap necessary to prevent rain water ponding and to promote runoff. The earthen cap was then seeded to grow a short-rooted protective grass cover. To preclude inadvertent human intrusion, a security fence surrounded the disposal sites. The near surface disposal method assumed that the nature and rates of natural processes acting on the earthen trench system would be sufficient to slow the movement of radionuclides from the disposal trenches to the accessible environment until they had decayed to acceptable background levels found in nature.

In 1973, the AEC asked the NAS to independently review the shallow-land disposal practices at its facilities. The AEC was particularly interested in identifying "undesirable existing conditions and disposal practices..." as well as identifying corrective actions, such as changes in current burial practices, changes in conditioning of materials for burial, and special treatment of the ground prior to disposal, etc. The AEC requested the review because routine monitoring at some of the AEC sites had begun to reveal that the disposal trenches were not containing the wastes and that radionuclides were being released. At the time, the AEC was particularly concerned about the long-term management of the TRU constituents of its wastes. In 1976, the NAS published its findings and recommendations following the review of solid LLW management practices at AEC facilities. Although the NAS found no serious deficiencies in past Federal disposal practices, it did make numerous administrative, as well as technical recommendations for the AEC to consider.

Early Performance Issues

After several years of operation, the West Valley, Maxey Flats, and Sheffield sites began to encounter surface and/or ground-water management problems. These problems, coupled with other early LLW disposal practices, resulted in the unexpected release and transport of radionuclides from the disposal sites. Key failure modes included waste container exhumation due to surface erosion; ground failures (subsidence) caused by inadequate waste container compaction and the migration of contaminated leachate from unlined disposal trenches. Because the disposal units were in effect "leaking," decisions were made to suspend operations and close the sites in the 1970s.

The remaining LLW sites had problems of a different type. The Governors of Nevada and Washington temporarily closed the Beatty and Richland sites, respectively, in 1979 as a result of waste packaging violations and transportation safety issues. When the volume of waste shipped to the South Carolina site began to increase because of closures and interruptions at the other sites, coupled with a large increase in the generation of LLW following the Three Mile Island incident, South Carolina was concerned that the facility would bear sole responsibility for the disposal of the Nation's commercial LLW. As a result, in 1979, the Governor of South Carolina ordered that waste acceptance operations be scaled back by 50 percent over a 2-year period (See Figure 1).

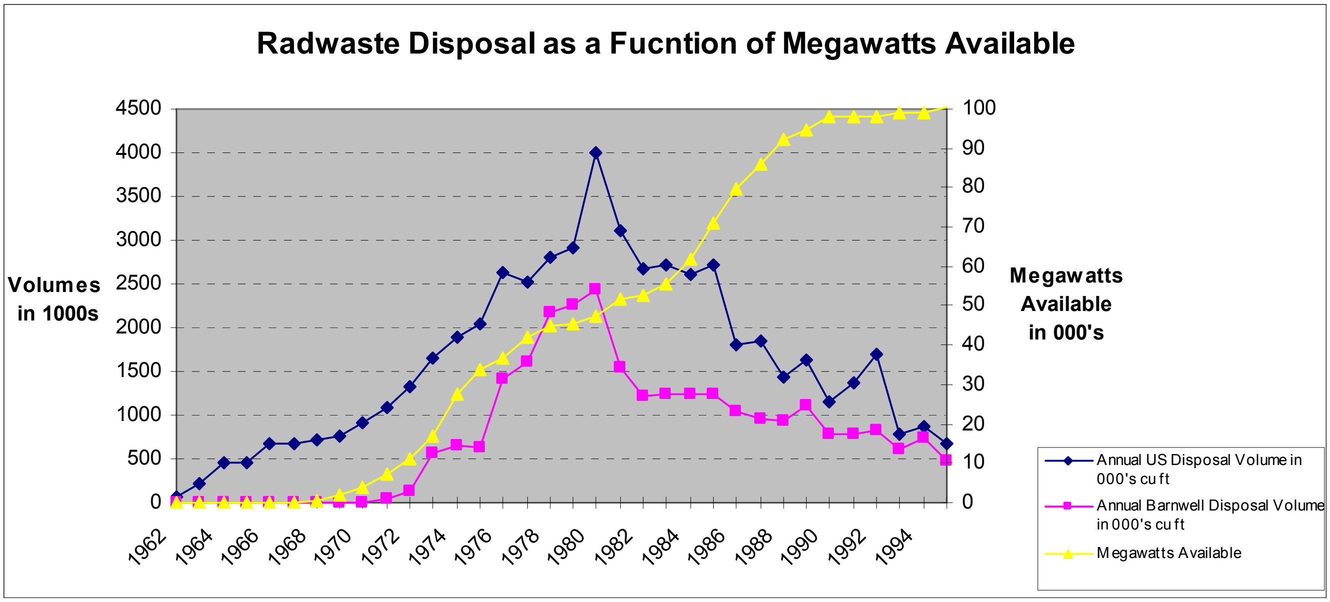


Figure 1

One can note from the above Chart that for 1962 until approximately 1980, waste volumes increased annually in proportion to reactor megawatts becoming available. In 1980, with the South Carolina Governor's order to reduce waste disposed at the Barnwell site by 50% over a two-year period (2.4 million ft^3 to 1.2 million ft^3), the trend of decreasing waste production started. It is interesting to note that the waste generated could have been diverted to the Washington site, but in fact did not and all waste generated has tended downward since 1980.

The reduction in waste generation was the result of many initiatives, including technological advances, major reductions in the extent of contaminated areas within power plants and overall better waste management practices. However, as is normally the case, the cost of LLW disposal trended upward at significant rates and to counter these rising costs, utilities continued to improve their waste management practices and also started to utilize volume reduction and other waste minimization efforts. These efforts included segregation, decontamination, minimizing exposure of materials and tools to the contaminated environment, sorting potential contaminated materials, and dewatering of resins versus solidification and evaporation. Some of the most effective volume reduction strategies were compacting, consolidating, and monitoring waste streams to reduce the volume of LLW requiring storage and to reduce the exposure of routine equipment to the reactor environment.

In 1986, a new source of volume reduction–fixed base waste processors–started to become a predominant. Their services included incineration, ultracompaction, decontamination, metals recycling, and other repackaging methodologies. As noted in Figure 1, waste volumes remained somewhat steady from 1982 until 1986, when the waste processor entered the picture and volumes started decreasing again.

Also in 1985, The Low-Level Radioactive Waste Policy Act of 1980 was amended and established a federal policy that commercial low-level radioactive waste can be most safely, efficiently and effectively managed by states on a regional basis. The act's objectives were to provide for new disposal capacity and to more equitably distribute the responsibility for managing this waste among the states. To encourage states to form compacts and develop new disposal facilities, congressionally approved compacts may prohibit the disposal of waste generated outside of their respective regions.

When the 1980 act was passed, there were three operating disposal facilities for commercial waste:

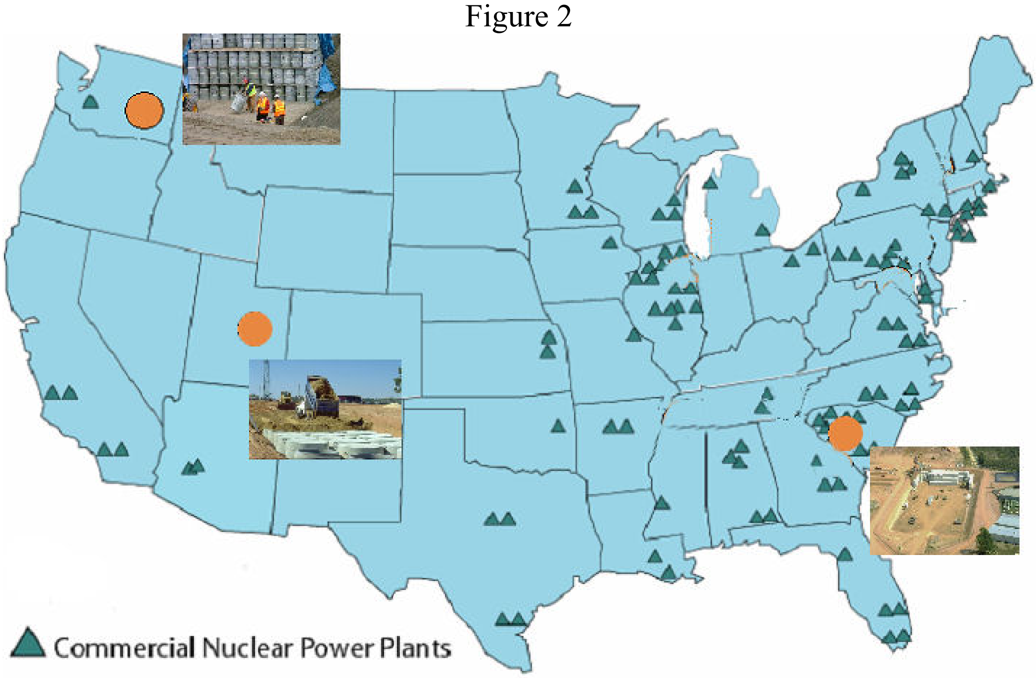
- Barnwell, South Carolina,
- Richland, Washington
- Beatty, Nevada

While the Beatty site has closed, both the Barnwell facility and the Richland facility are still operating and accept all classes of low-level radioactive waste for which states must provide disposal—classes A, B and C. In addition, the Clive, Utah, site started taking low levels of radioactive waste in 1991 and Class-A waste in 2000.

The Compact law started on a good footing, but over time socio-political issues prohibited progress. The people living in and around designated potential site areas did not want the waste in their backyard (NIMBY: not in my backyard). In the midst of the siting program, South Carolina pulled out of the Southeast Compact and formed an Atlantic Compact with New Jersey and Connecticut. The Hanford, Washington, site was already in the Northwest compact servicing 8 Northwestern States. While the Barnwell site continues to accept all USA waste, it is scheduled by law to cease this operation for the nation and only serve the Atlantic Compact after June 30, 2008.

As of July 1, 2008, only seven states will have access to a disposal facility that can take all three classes of waste, A, B, and C. The Utah site will continue to service the other states, but currently only for Class-A waste. This leaves some generators with concern about their Class B and C waste. (See Figure 2)

Figure 2



Current Waste Programs

As mentioned, the Barnwell site deadline of July 1, 2008, is imminent, and most waste generators will face a new challenge: how to deal with Class-B and -C waste. In addition, by current law, Barnwell is allowed to accept a maximum of 40,000 ft^3 of waste in fiscal year 2007 (July 1, 2006 to June 30, 2007) and 35,000 ft in fiscal year 2008 (July 1, 2007 to June 30, 2008). This has already forced generators outside the Northwest compact to assure as much waste as possible is maintained at the Class-A level and shipped to the Utah site. For the most part, the Barnwell site has become a "B&C" site. Fortunately, this is a small volume of waste in comparison to the total generated waste volume and consists mainly of higher activity primary resins and irradiated reactor components.

It is obvious that volume reduction is the key to maintaining reasonable costs and continuing disposition of waste, but this must be controlled in the future prevent processing from creating waste form that is greater than Class A.

The USA radioactive waste processors have literally consolidated over a period of years into to two major players, and a third processor that deals mainly with mixed waste (radioactive and toxic). Technologies utilized are summarized in Table 2.

Table 2

Technology	Waste Stream	Est. VR
Thermal Destruction	DAW	200:1
	Oil	∞
	Water	∞
	Resin	10:1
	Mixed Waste	∞
	Filters	200:1
Compaction	DAW	7:1
	Metals	4:1
Metal Melting	Carbon & Stainless	∞
Lead Smelting	Lead	∞
Decontamination	Metals	∞
Repackaging	Misc	3:1

While processing has been predominant in the USA, with the addition of the Utah site for Class a Waste, direct disposal is still considered a prime candidate for the direct disposition of Low Activity Waste. In all cases, a financial evaluation needs to be done to determine the best route for the generator. In some cases it is found that the cost of staffing, running and maintaining volume reduction equipment can exceed the cost for direct disposal. However, generators also factor any cost savings with total waste volume disposed to determine the final waste disposition path.

Other cost factors that must be considered to determine whether to use a processor or direct disposal are

- Disposal packages versus lower cost packages for shipping to a processor
- Handling at the generators site for packaging for processing or disposal
  - ✓ Staffing
  - ✓ Time
  - ✓ Personnel dose
  - ✓ Operational impact
- Location of the generator in relation to the processor/disposal site for transportation purposes

USA – Canada Waste Comparisons

While there are many similarities between Canada and the USA in waste processing methodologies, the competitive market and the much greater number of generating stations have led to a more aggressive approach to waste management in the USA with the installation of a greater variety of processing equipment. In comparing the USA utility market alone, it is clear that significantly more waste will be produced from the over 100 reactors (PWRs and BWRs) in the USA versus the 22 reactors in Canada.

Presently Hydro Quebec and New Brunswick Power store all of their wastes on site with some occasional third party processing for missed waste oils and chemical decontamination liquid. Ontario Power Generation consolidates their waste along with the Bruce Power waste and stores them at the Western Waste Management Facility with some occasional third party processing for mixed waste oils. While there are no future plans for shallow land burial in Canada, there are plans for a Deep Geologic Repository (DGR) to be located near the WWMF in Kincardine. The DGR is in the planning stages and is anticipated to be operational in the early 2020s.

As for waste processing, the main effort is at the WWMF where incineration of DAW and oil is performed.

Table 3 compares the waste programs in the USA with their equivalent programs in Canada. It is intended to be general as there are assuredly specific circumstances where the methodologies used may be different. In addition, the comments are the authors' speculations and possible recommendations and are not intended to be absolute.

Table 3

Processing/ Disposal Option	US Plant	Ontario Power Generation		Bruce Power		Hydro Quebec & New Brunswick Power		Other
		Regular	Potential	Regular	Potential	Regular	Potential	
On site Storage	✘	WWMF		WWMF		On Site		Chalk River
Final disposition	3 Shallow Land final disposition sites	DGR	3rd Party	DGR	3rd Party	✘	3rd Party	AECL repository
Volume Reduction								
Incineration								
DAW	3rd Party	WWMF		WWMF	3rd Party	✘	3rd Party	3rd Party
Oil	3rd Party	WWMF		WWMF	3rd Party	✘	3rd Party	3rd Party
Water	3rd Party	✘		✘	3rd Party	✘	3rd Party	3rd Party
Resin	3rd Party	✘		✘	3rd Party	✘	3rd Party	3rd Party
Mixed Waste	3rd Party	3rd Party		3rd Party		✘	3rd Party	3rd Party
Filters	3rd Party	✘		✘	3rd Party	✘	3rd Party	3rd Party
Compaction								
DAW	3rd Party	WWMF	Use incineration	WWMF	Use incineration	✘	Use incineration	Use incineration
Metals	3rd Party	Some	Use metal melt	WWMF	Use metal melt	✘	Use metal melt	Use metal melt
Filters	3rd Party	WWMF	Use Mobile supercompaction	✘	Use Mobile supercompaction	✘	Use Mobile supercompaction	Use Mobile supercompaction
Inicnerator Ash	3rd Party	✘	Use Mobile supercompaction	N/A	N /A	✘	N/A	N/A
Metal Melt	3rd Party	✘	3rd Party	✘	3rd Party	✘	3rd Party	3rd Party
Lead Smelting	3rd Party	✘	3rd Party	✘	3rd Party	✘	3rd Party	3rd Party
Decontamination	3rd Party	On site	3rd Party	On site	3rd Party	✘	3rd Party	3rd Party
Large Components	3rd Party	✘	3rd Party	✘	3rd Party	✘	3rd Party	3rd Party

In consideration of the comparisons in Table 3, it can be seen that using 3rd parties for processing is practical and allows Canada to benefit from the economics of the much larger USA market and to benefit from the greater variety of processing equipment and routes. This process has been proved beneficial for Canadian generators by have chemical decon liquids and mixed waste oils sent to 3rd party processing in the USA.

The most beneficial options for Canada at this time appear to be

1. Incineration of DAW. Oil, Water & Filters for organizations that do not have their own incineration capability. Incineration allows for complete destruction of the waste with ash becoming the waste of the processor.
2. Metal Melt – In this process metals are melted and reformed into shield blocks or other suitable shielding forms and reused solely in the nuclear market. This not only eliminates future waste liabilities, but also allows for the beneficial reuse of radioactive metals..
3. Lead smelting – Lead can be smelted and reformed into shielded containers and, as with metal melt, reused solely in the nuclear market.
4. Large Components – These components can be sized and used as feedstock material for the metal melt process as described in 2 above. This not only eliminates future waste liabilities while beneficially recycling the radioactive metals, but minimized the impact on future disposal in Canada as the current estimated final waste form promotes a volume increase due to packaging of the segmented components.

In principle, it is possible to consider the utilization of USA technologies and know how by the development of a facility in Canada using similar, appropriately scaled, equipment.

Conclusion

While the USA waste market has similarities to the Canadian market, there also remain many differences. The USA has historically focused on final disposition and Canada has focused on long-term storage. Today, the Canadian market in Ontario has realigned its direction to focus on long-term disposition of waste utilizing the DGR concept, while Canadian radioactive waste generators outside on Ontario remain focused on long-term storage of their waste.

Until such time that a final waste disposition answer is realized in Canada, reduction in waste generation, volume reduction of waste generated and long-term storage waste packages and waste forms remain the foremost consideration. The options offered by the larger USA market provides an opportunity for waste volume minimization and in many cases for complete removal of the waste form from the site thereby removing any ongoing storage costs and any concerns about the final cost of disposition.