NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

(2013 Update)

Watching Brief on Reprocessing, Partitioning and Transmutation

Canadians have expressed interest in knowing more about the possibility of recycling or reusing used nuclear fuel. Reprocessing and partitioning involves the separation of potentially fissile materials, such as plutonium, from used nuclear fuel through the application of chemical and physical processes. It should be noted that reprocessing by itself does not eliminate any of the radioactivity created in the used fuel. Instead, it merely separates and partitions it into several waste streams, including significant volumes of high-level radioactive waste, intermediate-level radioactive waste and low-level radioactive waste. A portion of the recovered fissile material can then be further processed into new plutonium-uranium mixed oxide (MOX) fuel and recycled into some current reactor types, including CANDUs. A few countries, such as France and the United Kingdom, operate commercial reprocessing facilities. Recycling of used light water reactor fuel as MOX is currently practised on a commercial scale in several countries with reprocessing services provided by the commercial facilities in France and the United Kingdom. Transmutation is a possible next step and involves the conversion of long-lived radionuclides into shorter-lived ones through irradiation in an accelerator-driven system (ADS) and/or fissioning in a fast neutron reactor. This is not currently practised, although research to demonstrate its feasibility is underway in several countries. Prototype fast neutron reactors have been built and operated in several countries for power production purposes. They are considered to be part of sustainable nuclear fuel cycles because they have the benefit of being able to extract additional energy from depleted uranium and from the actinides extracted from the recycled fuel.

These options were examined as part of the original NWMO study that led to the Adaptive Phased Management (APM) concept [Jackson, 2003, 2005]. As part of its "adapting to change" responsibility, the NWMO has committed to keep a watching brief on developments in reprocessing, partitioning and transmutation (RP&T). This watching brief summarizes recent research and development in RP&T.

Executive Summary

There are three basic nuclear fuel cycles: "open" or once through (in which the fuel is irradiated in the reactor, then considered to be waste when it is removed); partial recycle (in which the used fuel is reprocessed to recover plutonium, converted to MOX fuel and reused once in current reactor types); and "closed" (in which the used fuel is reprocessed to recover plutonium and other actinides, then used to start up advanced fast neutron reactors (FRs)). The fast reactor used fuel is then reprocessed and continuously recycled in the FRs to extract additional energy. Depending on the configuration of the reactor, additional

amounts of natural or depleted uranium or reprocessed used fuel can be added to replenish the fuel consumed in the fast reactor. Other variations can include different combinations of reactors, such as a two-tier (or “double strata”) cycle, including combinations of conventional reactors (with or without MOX fuel), fast reactors and/or accelerator-driven systems.

As shown in Table 1, Canada, as well as most other nuclear power generating countries, currently practises the open fuel cycle. A few countries, such as Belgium, France, Japan and Switzerland, use or have used partial recycling, with the used MOX fuel either stored as waste or awaiting future recycling into fast reactors. This recycling is generally done for strategic national energy security reasons, not for economic or waste management reasons. (Indeed at current uranium prices, recycling used fuel is considerably more costly than the open cycle and does not eliminate the need for long-term management of residual high-level wastes, as well as the additional low- and intermediate-level wastes produced during the recycling process.) There are no countries that currently practise a fully closed fuel cycle on an industrial scale.

Work continued in 2013 in various countries and international collaborative programs to review and assess the technology and implications of advanced fuel cycles, including RP&T. Findings were presented at several international conferences, including the annual World Nuclear Fuel Cycle conference (April 2013, Singapore), the International Atomic Energy Agency (IAEA) Fast Reactor conference (March 2013, Paris, France), the International Conference on Emerging Nuclear Energy Systems (May 2013, Madrid, Spain), the 2nd International Workshop on Technology and Components of Accelerator Driven Systems (May 2013, Nantes, France) and GLOBAL 2013 (September 2013, Salt Lake City, United States). Papers presented at these conferences showed that some advances are being made in the science and technology underlying RP&T and advanced fuel cycles, as well as in devising schemes to transition from current fuel cycles to the advanced ones. However, all these programs currently focus on recycling enriched uranium fuels, mostly light water reactor (LWR) fuels, into next-generation fast reactor systems, and subsequent further continuous recycling of the advanced reactor fuels. Additional research and development would be required to assess their applicability to used CANDU fuels. While some of the advanced fuel cycles are theoretically sustainable once they reach equilibrium, there are still many scientific and engineering challenges (such as development of suitable materials of construction for the very harsh conditions present in the advanced reactors and the scale up of lab-sized processes to full-sized), as well as socio-political and economic challenges, which must be solved before they can be implemented on an industrial scale.

It is not clear whether there are any benefits to waste management from advanced fuel cycles. While some of the advanced fuel cycles can address potential waste management issues (such as increasing the waste storage density in some repository designs or using previously separated plutonium), most of them make waste management issues more complex because they result in a number of chemically very complicated radioactive waste streams that must be suitably processed and conditioned before being placed in a deep geological repository anyway.

Cost is also an important consideration. In order to be successfully deployed on a commercial basis, the lifecycle cost of producing electricity with them must be lower than for other production methods, including current nuclear power plants and non-nuclear technologies. A major study published in 2013 by the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA) [OECD/NEA, 2013a] looked at lifecycle costs for various fuel cycle options and concluded that the once through fuel cycle was the least expensive at this time. The lifecycle costs include development, construction, operation, maintenance, decommissioning, and waste management related costs both for the power plant and for the associated fuel cycle facilities and transportation systems. All the proposed advanced fuel cycle schemes are based on the assumption of ongoing or expanding nuclear power programs for many decades or even centuries, as discussed in other studies on implementing the advance fuel cycles [OECD/NEA, 2012b, 2013b].

Beyond the primary benefit of energy security with these systems, a secondary benefit of the advanced fuel cycles is that it may reduce the demand for space in a high-level waste repository. However, this benefit can only be realized if alternate methods of managing the large volumes of long-lived intermediate-level waste resulting from reprocessing can be found and some of the separated fission product wastes are stored for several hundred years prior to placement in a repository to allow the decay heat to dissipate. Otherwise, there is no significant benefit to the size or safety of a deep geological repository for high-level waste and used fuel.

Similar to previous NWMO watching briefs on RP&T, the basic conclusions of this review remain unchanged:

» Some form of deep geological repository is required regardless of the fuel cycle in order to be able to deal with long-lived radioactive wastes.

» The waste management benefits of advanced fuel cycles are uncertain. Although RP&T has the potential to reduce the volume of used nuclear fuel and high-level waste for placement in a deep geological repository (when combined with advanced fuel cycles using fast reactors), it also significantly increases the quantity of long-lived low- and intermediate-level waste (which also requires a deep repository for long-term management) and does not significantly reduce the underground footprint of the repository. (For high-level waste and used fuel, repository size is based primarily on heat generation rate, not on volume of the waste. This is a function of the amount of energy extracted from the fuel, so it remains relatively constant per unit energy produced, regardless of fuel cycle.)

» Advanced fuel cycles are at least many decades away from being ready for wide-scale commercialization due to the time required for the technical research, and to develop and demonstrate the reactor technologies. High cost and broad public acceptance issues that may accompany the "first-of-a-kind" designs may also inhibit their demonstration and deployment in the near term. Once a decision has been taken to deploy such fuel cycles, they will take many decades further to fully transition from current fuel cycles to the new ones, and decades to centuries to realize any waste management benefit from their implementation [OECD/NEA, 2013b].

» Based on the current cost of uranium, the lifecycle cost of advanced fuel cycles is higher than once through fuel cycles, due to the high costs of developing and constructing the new generation reactors, reprocessing facilities and fuel fabrication plants. If such fuel cycles could be developed, the cost and project risks for implementing them on a commercial scale would currently make them very unattractive and financially risky for utilities to deploy.

» Some countries currently engaged in fuel reprocessing, such as the United Kingdom, are considering discontinuing this practice due to the lower cost option of direct placement of used fuel in a deep geological repository. Other countries that have been developing commercial scale fuel reprocessing capability, such as Japan, are reconsidering their future fuel cycle options.

Table 1: Summary of Current Status of Reprocessing for the Nuclear Power Fuel Cycle

Country	Commercial Scale Reprocessing Facility		Currently Send Used Fuel for Reprocessing in Other Country	Decided to Cease Having Used Fuel Reprocessed	Planning Direct Placement of Used Fuel in a Repository
	Existing	Planned			
Belgium				✓	✓
Canada					✓
China(3)		✓			✓ (4)
Czech Republic				✓ (7)	✓
Finland				✓ (7)	✓
France(3)	✓ (2)				
Germany				✓	✓
Hungary				✓ (7)	✓
India(3)	✓				
Japan		✓ (6)	✓		
Korea, Rep. of					✓
Mexico					✓
Netherlands			Until 2015(5)	✓	✓
Pakistan(3)					
Romania					✓
Russia(3)	✓				
Slovakia				✓ (7)	✓
Slovenia					✓
Spain					✓
Sweden				✓	✓
Switzerland				✓	✓
United Kingdom(3)	✓ (1)			✓	✓
Ukraine				✓ (7)	✓
United States(3)				✓	✓

(1) The United Kingdom plans to cease reprocessing at end of current contracts.
(2) EDF recently planned to cease reprocessing its used fuel, but was required to continue for national policy reasons.
(3) China/France/United Kingdom/Russia/United States/Pakistan/India currently reprocess for military reasons.
(4) China plans direct placement of its used CANDU fuel in a repository.
(5) Used fuel sent to France for reprocessing.
(6) Facility has been constructed and is undergoing test operation, but policy currently under review.
(7) Some used fuel were sent to former Soviet Union for reprocessing. Practice terminated at end of USSR era.

These conclusions are consistent with those stated in previous NWMO watching brief reports [Jackson, 2008, 2009, 2010; NWMO, 2011, 2012a].

Discussion

The NWMO has kept a watching brief on RP&T developments over the past few years. Previous detailed technical reports [Jackson, 2008, 2009, 2010] and summary watching brief reports [NWMO, 2011, 2012a] are available on the NWMO website. This present report focuses on a summary of recent international activities since the 2012 watching brief was published.

As reported in previous watching briefs, the U.S. Blue Ribbon Commission on America's Nuclear Future (BRC) conducted an extensive review in 2010 and 2011 of available options and technologies for management of the back end of the nuclear fuel cycle in the United States. In its final report [U.S. BRC, 2012a], the BRC stated (among other things):

» *The conclusion that disposal is needed and that deep geologic disposal is the scientifically preferred approach has been reached by every expert panel that has looked at the issue and by every other country that is pursuing a nuclear waste management program.*

» *Technologies exist today or are under development that would allow spent fuel to be at least partly re-used; systems have also been proposed that could – in theory and at some point in the future – possibly allow for the continuous recycle of reactor fuel, thereby fully "closing" the fuel cycle. Substantial uncertainties exist, however, about the cost and commercial viability of the more advanced of these technologies; in addition, significant concerns have been raised about their impacts on weapons proliferation risks and other aspects of the fuel cycle (e.g., the production of LLW) even if they could be successfully deployed.*

» *…no currently available or reasonably foreseeable reactor and fuel cycle technology developments – including advances in reprocessing and recycling technologies – have the potential to fundamentally alter the waste management challenge this nation confronts over at least the next several decades, if not longer.*

» *In any event, we believe permanent disposal will very likely also be needed to safely manage at least some portion of the commercial spent fuel inventory even if a closed fuel cycle were adopted.*

Additional detailed reports were also issued by each of the three BRC subcommittees (Reactor & Fuel Cycle Technology, Transportation & Storage, and Disposal) [U.S. BRC, 2012b, c, d]. The U.S. government is still considering how it will respond to the BRC recommendations.

Research on RP&T and advanced fuel cycles is ongoing in the United States and other parts of the world. Findings were presented at several international conferences, including the annual World Nuclear Fuel Cycle conference (April 2013, Singapore) [WNA, 2013], the IAEA Fast Reactor conference (March 2013, Paris, France) [IAEA, 2013a], the International Conference on Emerging Nuclear Energy Systems (May 2013, Madrid, Spain) [ICENES, 2013], the OECD/NEA 2nd International Workshop on Technology and Components of Accelerator Driven Systems (May 2013, Nantes, France) [OECD/NEA, 2013c] and GLOBAL 2013 (September 2013, Salt Lake City, United States) [GLOBAL, 2013]. Papers presented at these conferences, as well as technical reports published by the OECD/NEA [e.g., OECD/NEA, 2011, 2012b, 2012c, 2013a, 2013b], IAEA [e.g., IAEA, 2012, 2013b, 2013c], U.S. Nuclear Regulatory Commission [U.S. NRC, 2012], and various international collaborative projects (such as the European Sustainable Nuclear Energy Technology Platform [SNETP, 2013] and Advanced Fuels for Generation IV Reactors: Reprocessing and Dissolution [ASGARD, 2013] projects), showed that advances are being made in the science and technology underlying RP&T and advanced fuel cycles. Some of the potential advanced fuel cycle concepts and options are discussed next.

All the commercial nuclear power reactors in operation around the world today are based on thermal neutrons. In this type of reactor, a moderator is used to slow down (or thermalize) the high energy neutrons produced by the fission reaction so that they can induce further fission in the U-235 and/or Pu-239 isotopes in the nuclear fuel. Moderating materials include normal or light water (used in most non-CANDU reactors around the world), heavy water (used in CANDU reactors) and graphite (mainly used in gas cooled reactors). The moderating materials have different properties for interacting with the neutrons. For example, heavy water moderated reactors can sustain a nuclear chain reaction in natural (un-enriched) uranium, which contains about 0.7% of U-235 with the rest being U-238. On the other hand, light water (used in many other places in the world in boiling water reactors (BWRs) and pressurized water reactors (PWRs), collectively known as light water reactors or LWRs) requires a higher concentration of U-235 (generally 3% to 5%) to work. Producing this higher concentration is known as enrichment. A byproduct of this process is depleted uranium (DU), which has a reduced U-235 content of around 0.3% and is now generally considered to be a waste by countries that operate enrichment facilities. Operation of current reactor types requires a continuous supply of fresh uranium as a source of the fissile U-235. As noted below, the DU from the enrichment process is a potential fuel source for some advanced reactor fuel cycles.

There are two main technical reasons why a RP&T program or advanced fuel cycle could be implemented:

» to improve national energy security (i.e., to recover additional energy from the used nuclear fuel and reduce reliance on the need for fresh uranium); and/or

» to reduce burdens on a deep geological repository (i.e., to allow the waste from more nuclear energy to be placed in a repository of a given size).

The first reason is based on the premise that uranium is too scarce or costly to use in a once through fuel cycle and should be preserved, or that indigenous supplies are limited and that access to foreign supplies is unreliable. The second reason is based on the premise that used fuel from existing reactors can be recycled into fast reactors, that there will be an ongoing nuclear power program for many decades (or even centuries) and that suitable repository space to manage the resulting wastes will be scarce. Both reasons also assume that other energy alternatives are more costly and nuclear energy is the most economic choice for a given country. A third reason is also sometimes quoted: partitioning and transmutation will reduce the “radiotoxicity” of the waste by transmuting the transuranic elements. However, while transmutation does eliminate the longer-lived transuranic elements, it does not improve the overall safety of a repository because the transuranic elements have very low mobility in the natural environment and do not migrate from the repository to the biosphere. The long-lived mobile fission products, such as I-129, which are not removed by transmutation, are generally the key radionuclides for long-term repository safety assessments [Kessler et al., 2012; NWMO, 2012b; Sandia, 2012].

In any event, fully implementing RP&T requires the commercial scale deployment of advanced systems, such as fast reactors as shown in Figure 1, or accelerator-driven systems, as well as their associated infrastructure such as reprocessing plants and fuel fabrication facilities. Although fast reactors have been in existence since the 1950s, they have yet to achieve widespread commercial acceptance and deployment. See for example [IAEA, 2012, 2013c] for descriptions of various fast reactor prototypes and their operating histories.

Fast reactors do not use a moderator. They can be used to extract the energy from the U-238, as well as other actinides that are created in a reactor (such as various isotopes of plutonium, americium, neptunium, etc.). In the case of U-238, this is done by first converting the U-238 to Pu-239 via neutron capture and subsequent radioactive decay, and then inducing fission in the Pu-239 by another neutron. As the U-238 is consumed, make-up uranium can be added, either from reprocessed thermal reactor fuel or from the depleted uranium from enrichment processes. The use of depleted uranium is generally considered to be the better option, since it is widely available, has very low specific radioactivity and can be more easily handled, whereas the reprocessed uranium tends to be very radioactive as a result of the buildup of more radioactive isotopes (e.g., gamma emitting daughter products of the U-232 decay chain).

Current fast reactor concepts operate at very high temperatures (typically 400°C or more) and use liquid metals (e.g., sodium or lead), molten salts (e.g., sodium fluoride mixtures) or gases (e.g., helium) as coolants rather than water or heavy water. The high temperatures and neutron fluxes combined with the very corrosive liquid metal coolants create very harsh conditions for any reactor materials. Investigation of materials that can withstand these conditions for several decades of reactor operation is one of the ongoing areas of research.

Depending on the details of the design, the fast reactor systems can operate in three modes:

- *burner*, where the reactor consumes more fissile material (i.e., actinides) than it produces. Note that this is the only mode that will eliminate the actinides from current inventories of used nuclear fuel;
- *self-sustaining* or *break-even*, where the reactor is in equilibrium and consumes all the fissile material that it produces; and
- *breeder*, where the reactor produces more fissile material than it consumes (this supplies more fuel for an ever-expanding nuclear program).

All three modes of operation require an initial core loading of highly enriched U-235 or Pu-239 to start up the reactor. The U-235 would be obtained from enrichment of fresh uranium to much higher levels than is currently practised for commercial nuclear power reactors (i.e., greater than 20% U-235 vs. 3% to 5% for light water reactors). The Pu-239 would be obtained from the reprocessing and partitioning of current light water reactor used fuel. Once started, the reactor can create its own fissile material *in situ* from U-238 and other actinides in the fuel.

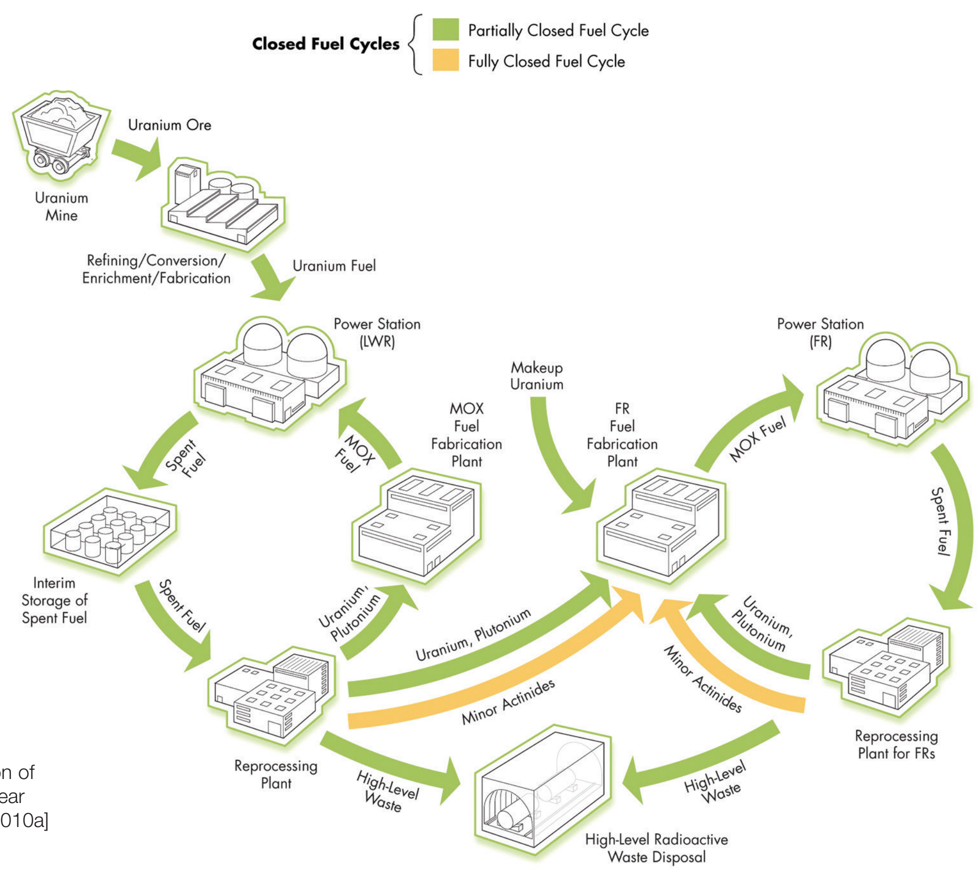

Figure 1: Illustration of an advanced nuclear fuel cycle [EPRI, 2010a]

Cost is also an important consideration. In order to be successfully deployed on a commercial basis, the lifecycle cost of producing electricity with advanced reactors and fuel cycles must be lower than for other production methods, including current nuclear power plants and non-nuclear technologies. A major study published in 2013 by the OECD/NEA [OECD/NEA, 2013a] looked at lifecycle costs for various fuel cycle options and concluded that the once through fuel cycle was the least expensive at this time. The lifecycle costs include development, construction, operation, maintenance, decommissioning, and waste management related costs both for the power plant and for the associated fuel cycle facilities and transportation systems. Other studies, such as [INL, 2012], have examined the detailed cost estimates for constructing and operating various types of advanced reactors.

All the proposed advanced fuel cycle schemes are based on the assumption of ongoing or expanding nuclear power programs for many decades or even centuries, as discussed in other studies on implementing the advanced fuel cycles [OECD/NEA, 2012b, 2013b]. The transition from thermal reactors to fast reactors is the subject of several recent technical and policy studies. Assuming that a country has access to large scale reprocessing facilities for thermal reactor fuel, the cost of obtaining enough plutonium for an initial core loading is in the $1-billion range [MIT, 2011]. (Once started up with plutonium or other enriched fissile material, the reactor can be refueled with depleted uranium or processed used nuclear fuel from thermal reactors.) In addition to being a significant cost, the rate at which the plutonium can be supplied limits the speed at which the fast reactors can be deployed. Most scenarios studied (e.g., in France and Japan) require 50 to 100 years or more to transition from thermal reactors to fast reactors in a step-wise fashion and a further 100 to 200 years to effectively consume the used fuel from current LWRs. (See for example, [MIT, 2011], [OECD/NEA, 2009, 2012b, 2013b], and Warin and Boullis in [OECD/NEA, 2012a].) This long transition time imposes a commitment on future generations to operate and maintain a nuclear power program (including periodic replacement of the nuclear fleet and associated fuel cycle facilities), but it also gives them access to significant quantities of low-carbon energy, should they choose to exploit this source of energy. Many of the studies point out that in addition to the used nuclear fuel, there is sufficient depleted uranium available to sustain such a system globally for many centuries, if not millennia.

Another area of research is in used fuel reprocessing and partitioning. Current reprocessing technology is based on wet chemistry. The used fuel is dissolved in concentrated acids, then subject to a series of chemical steps to separate out the various constituents. Descriptions of the various process used can be found in the technical literature, such as [OECD/NEA, 2012c]. Since the used nuclear fuel and the resulting products are highly radioactive, all this needs to be done using remotely operated, heavily shielded systems. Even routine maintenance needs to be done remotely due to residual contamination in the equipment. The process also results in large volumes of chemically complex wastes. Some of the material can be recycled back into the process, but it eventually ends up as waste that must be stabilized for storage, then eventually placed in a repository [MIT, 2011].

Most fast reactor scenarios rely on different fuel types than those that are currently used, such as metallic fuels or silicon carbide/graphite coated fuel particles. These fuel types are not compatible with the current wet chemical processing technology used for light water reactor uranium oxide based fuels. A non-aqueous technology ("pyro-processing") is being developed for these fuels. However, although this has been employed in prototype fast reactors in the past (e.g., the U.S. Experimental Breeder Reactor (EBR) program of the 1950s to 1980s [IAEA, 2012]) and has been proposed for other systems, such as IFR and PRISM [Triplett et al., 2012], pyro-processing has not yet achieved wide-scale commercial implementation. (See for example, Iizuka et al. in [OECD/NEA, 2012a].) In addition, fast reactors require very complex reprocessing facilities to remove the buildup of undesirable nuclides in the fuel resulting from multiple recycling. Remote handling is also required for recycled fuel fabrication due to the buildup of nuclides, which emit high-energy gammas.

Several countries that operate both CANDU type reactors with natural uranium fuel and light water reactors with enriched uranium fuel (such as China, South Korea and India) are also researching or developing synergistic fuel cycles for managing their used light water reactor fuels, such as DUPIC ("Direct Use of PWR fuel In CANDU") and NUE ("Natural Uranium Equivalent"). After mechanical, thermal and/or chemical processing to resize the fuel pellets and remove volatile fission products, their used light water reactor fuel is reconfigured as CANDU fuel bundles and introduced into their CANDU reactors to extract additional energy. Note that these technologies are designed for managing light water reactor fuels and are not applicable in Canada, since Canadian utilities do not currently operate light water reactors and the technologies are not applicable to recycling of used CANDU fuel in other CANDU reactors.

Although current research programs show the wide variety of work that is being carried out on very specific topics in a number of countries, they also demonstrate that transmutation technology is still far away from wide-scale practical implementation since none of the work has progressed beyond the laboratory environment. There are many basic technical challenges facing these advanced technologies, such as development of suitable materials to withstand the very high temperatures, pressures and/or corrosive nature of the process fluids while operating in the high-energy and high-flux neutron fields required in the core for these reactors, as well as the development of suitable fuel matrices [OECD/NEA, 2011]. Some of these challenges related to materials and fuels would be "showstopper" issues for the advanced reactors if they cannot be resolved. However, the potential benefits of advanced fuel cycles have resulted in the establishment of various international consortia (e.g., the Generation IV International Forum (GIF)) and commercial entities pursuing various designs and fuel cycle options.

Note also that used nuclear fuel contains a number of commercially valuable conventional elements such as platinum group metals and rare earths. Potentially, these could be extracted using advanced reprocessing and chemical techniques if a cost-effective method can be developed to remove any residual radioactivity.

Conclusions

A number of comprehensive technical and strategic reviews of RP&T programs and issues were carried out in recent years. These studies all reached very similar conclusions, which are consistent with previous NWMO watching brief reports

» Some form of deep geological repository is required regardless of the fuel cycle in order to be able to deal with long-lived radioactive wastes.

» It is not clear whether there are any benefits to waste management from advanced fuel cycles. The use of advanced fuel cycles does not significantly reduce the underground footprint of the repository when the large volumes of complex, long-lived secondary wastes are taken into account.

» Although prototype fast reactors have been in existence since the 1950s, advanced fuel cycles are still many decades away from being ready for widespread commercialization due to the time required for additional technical research to improve the materials and reliability of the reactors and supporting fuel cycle facilities. In addition, many more decades are required to fully transition from current reactors to advanced fuel cycles.

- The use of depleted uranium is generally considered to be the better option as a fast reactor makeup fuel over the use of recycled thermal reactor fuel, since it is widely available, has very low specific radioactivity and can be more easily handled, whereas the reprocessed uranium or used fuel tends to be very radioactive as a result of the buildup of more radioactive isotopes (e.g., gamma emitting daughter products of the U-232 decay chain).

- Broad public acceptance issues related to siting and construction of large scale "first-of-a-kind" nuclear facilities are also likely to delay the demonstration and deployment of advanced fuel cycles in the near term in many countries.

- The lifecycle cost of advanced fuel cycles is higher than once through fuel cycles, due to the high costs of developing and constructing the new generation reactors, reprocessing facilities and fuel fabrication plants. However, some countries with rapidly expanding energy needs have chosen to pursue advanced fuel cycles for national energy policy reasons, while other countries are considering them to deal with specific issues, such as previously separated plutonium.

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