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MULTILATERAL SPENT FUEL MANAGEMENT EFFORTS: NONPROLIFERATION AND ENERGY IMPLICATIONS IN THE ASIA PACIFIC

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1. Introduction

Management of spent nuclear fuel in the Asia Pacific will be a growing challenge in coming decades as the region continues its rapid economic and nuclear energy expansion. Accompanying this growth has been skyrocketing energy demand. The capacity of nuclear energy in the Asia Pacific is expected to increase by approximately 50% by 2035.[1] In fact, of the 66 reactors under construction worldwide, 47 are being built in the Asia Pacific region alone.[2] In a sense, the area is experiencing the so-called 'Nuclear Renaissance', which could simultaneously increase proliferation risks while fueling economic growth and political stability. And because 'Asia Pacific' includes North America, Oceania, East Asia, Southeast Asia and, by some definitions, South and Central Asia as well as the Middle East, the demand for nuclear energy in particular is expected to continue. Consequently, the Asia Pacific region will soon face important decisions about how to support and implement the necessary infrastructure for nuclear energy expansion and deal with the waste, while also meeting all nonproliferation obligations under the Treaty on the Non-Proliferation of Nuclear Weapons (NPT).

One option for dealing with spent nuclear fuel that should be considered is multilateral spent fuel management. Such an effort could help reduce risks associated with safety, proliferation and security of nuclear energy. While the original idea of multilateral spent nuclear fuel management is a decades-old concept, no official plan has been developed because of challenges related to cost, liability, transportation, export controls, international commerce, and nonproliferation, to name a few. Nonetheless, as more and more newcomer countries decide to develop nuclear energy, but do not yet have a strategic plan or the financial means to deal with the waste, the international community may need to take a more proactive approach in developing a multilateral effort, particularly with respect to geological repositories and interim dry storage. Risks and benefits will need to be analyzed, while the role of such an effort in the revival of the Nuclear Renaissance will need to be evaluated. This paper provides an overview of spent nuclear fuel management efforts in the Asia Pacific region and attempts to analyze the possible benefits and feasibility of a multilateral approach.

2. Background and Status of Spent Nuclear Fuel Management

2.1. Background

The concept of multilateral spent nuclear fuel management has been a part of the discussion on international nuclear technology management since the emergence of the Baruch Plan in 1946. And since the discovery of plutonium (Pu) in the early 1940s, the risk of spent fuel with respect to proliferation was clearly recognized. In addition, the Organization for Economic Cooperation and Development (OECD) and the Nuclear Energy Agency (NEA) have explored concepts regarding multilateral spent nuclear fuel management since the 1970s from the viewpoint of

[1] "World Energy Outlook 2013", IEA 2013

[2] "Reactor Status Reports" IAEA website. 2015

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nuclear nonproliferation, safety and security. Other groups, such as the Association for Regional and International Underground Storage (ARIUS)[3] and the European Repository Development Organization (ERDO) Working Group,[4] are exploring options for establishing joint waste management facilities, particularly in Europe.

Attempts to internationalize nuclear materials management/storage goes back to Article XII A.5 of the IAEA Statute. From this paragraph came the concept of 'International Plutonium Storage' that provided for the management of special fissionable materials by the Agency:

> "…to require deposit with the Agency of any excess of any special fissionable materials covered or produced as a by-product over what is needed for the above-stated uses in order to prevent sotck-piling of these materials, provided that thereafter at the request of the member or members concerned special fissionable material so deposited with the Agency shall be returned promptly to the member or members concerned for use under the same provisions as stated above."[5]

While the concept was extensively evaluated by two separate experts groups between 1978 and 1982, the idea never materialized. States were not willing to forgo their control over valuable nuclear materials. Furthermore, the original nonproliferation concerns had by that time lost their momentum in comparison to 1957 as a consequence of the advance of safeguards under the NPT since 1970.

In the 1990s, there was some thought put into developing the concept into efforts such as the proposed Wake Island nuclear storage and leasing facility,[6] and the Pangea project to establish international repositories in Australia,[7] but no concrete actions were taken.[8] Wake Island was proposed by a U.S.-based group, 'U.S. Fuel and Security', in the 1990s with the support of Russia involving storage and fuel leasing in the Pacific Ocean. Strong opposition from local communities and the U.S. government prevented the proposal ultimately from gaining traction. The Pangea project idea evolved from individuals who had been involved in a repository study group in Australia in 1997. Organizations from Canada, the U.S., the U.K. and Switzerland funded the effort and though Western Australia was identified as a preferred region for technical and geological reasons, political opposition prevented it from moving forward.

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[3] Association for Regional and International Underground Storage (ARIUS). (*"Promoting concepts for socially acceptable, international, and regional solutions for environmentally safe, secure, and economic storage and disposal of long-lived radioactive wastes.")* http://www.arius-world.org.

[4] European Repository Development Organization (ERDO) Working Group. http://www.erdo-wg.eu/Home.html.

[5] *Multilateral Approaches to the Fuel Cycle*, p. 115, IAEA. 2005.

[6] "Developing multinational radioactive waste repositories: Infrastructural framework and scenarios of cooperation". IAEA-TECDOC-1413, 2004.

[7] Ibid

[8] Ibid.

Other efforts associated with multilateral spent fuel management facilities in the 2000s included ideas such as establishing a storage site in Mongolia. Discussions about Mongolia's possible acceptance of spent nuclear fuel from the U.S. and Japan became public in May 2011.[9] Ultimately, however, these plans were dismissed and Mongolian authorities denied that negotiations on the topic ever occurred.[10]

In 2004, the IAEA published several reports on multilateral spent nuclear fuel management primarily for emerging nuclear energy countries as the so-called Nuclear Renaissance was gaining momentum and the risks for nuclear security, safety and safeguards were recognized. Major developed countries followed and suggested their own initiatives. The Global Nuclear Energy Partnership (GNEP), led by the U.S., was the most influential. These initiatives led to several achievements, particularly on the front-end such as development of proposals on assured nuclear fuel supply.[11] Since then, the OECD/NEA, GNEP's successor, the International Framework for Nuclear Energy Cooperation (IFNEC), ARIUS and the ERDO working group continue to discuss multilateral efforts for the back-end of the fuel cycle. As of today, however, a substantive international plan for next steps has not been developed. Below, we consider a few options: Domestic disposal, take-back programs, sending waste to a third party country, and multilateral spent nuclear fuel management.

2.2. Status and General Practice: Domestic Disposal

The options for spent nuclear fuel management include, 1.) Domestic disposal, 2.) Take-back by suppliers, 3.) Sending waste to a third party country, and 4.) Multilateral interim storage or disposal. Current general practice is to manage spent nuclear fuel domestically. In other words, disposal or interim storage is handled by the user countries themselves. Even in cases whereby countries request nuclear energy partners to reprocess their spent fuel on their behalf, high-level, un-reprocessed radioactive waste is often returned to the original user countries. In some parts of the Asia Pacific such as Japan, this is the general practice. Countries like the U.S., Japan and the Republic of Korea (ROK), however, rely mainly on domestic management of their spent fuel. For example, in its 2013 long-term spent fuel management strategy,[12] the U.S. plan includes interim and on-site dry storage as well as suggestions for geological repositories. Japan

[9] "Japan, U.S. plan nuclear waste storage in Mongolia." Reuters , 8 May 2011, http://www.reuters.com/article/2011/05/09/energy-nuclear-mongolia-idUSL3E7G80HD20110509

[10] According to International Panel on Fissile Materials "Managing Spent Fuel from Nuclear Power Reactors" (2011), the Embassy of Mongolia in Vienna also issued a statement which denied plans to bring nuclear waste to the country. The statement largely repeated official statements issues in March 2011. It states that "[The] Law on Nuclear Energy [...] does not envisage import of nuclear waste from other countries. Also Article 4 of Mongolia's law regarding its nuclear-weapon-free status clearly prohibits dumping or disposing of.... nuclear waste [...]. Moreover, Article 4.1 of Mongolia's law on exporting and banning import and trans-border shipments of dangerous waste unequivocally bans import of dangerous waste for the purpose of exploiting, storing, or depositing."

[11] They include 'IAEA Low Enriched Uranium (LEU) Bank', 'American Assured Fuel Supply', and the 'International Uranium Enrichment Centre' in Russia.

[12] "Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste." U.S. Department of Energy (DOE), 2013.

is also exploring its geological repository options and though it maintains an interim storage facility in Aomori, it began to officially improve the site selection process[13] for a repository in 2014. In the ROK, efforts to establish an interim storage facility and low- and intermediate-level radioactive waste disposal repositories began in 1986.[14] After over two decades of planning, operations at the Gyeongju disposal facility are now scheduled to begin in the near future.[15] The ROK is also in the process of evaluating two conceptual designs for a geological repository, including one for direct disposal of spent nuclear fuel (KRS concept) and one for wastes from pyroprocessing of spent fuel (A-KRS concept).[16] Nonetheless, significant challenges remain in countries such as the U.S., Japan and the ROK, namely cost, geological rock formation, consensus-based site selection, and seismic activity. And despite decades of research focused on the design and safe operation of repositories, there remain few successful cases of repository design, development, and operation within the nuclear energy community. Because of these challenges, including in more advanced nuclear energy states, some experts have expressed concern that it may be even more difficult for emerging countries to dispose of their spent fuel domestically. This is in part due to the fact that emerging nuclear energy countries such as Turkey, Vietnam and the United Arab Emirates (UAE) have no official plan for spent fuel management yet.

Despite some of the difficult issues surrounding the design and development of geological repositories, such as site selection, many countries continue to pursue domestic disposal options because each country is responsible for the waste generated within its borders. For example, the U.S., Japan, and the ROK all use domestic, on-site or interim dry storage to handle their nuclear waste because of the basic necessity to store it until it can be disposed of or processed. There is also some hope for technological innovation. Countries such as Japan are of the view that 4th generation reactors will help reduce high-level radioactive waste and shorten the time period for which radioactivity from such waste declines. Fast breeder reactor technology is thought to help reduce high-level radioactive waste by as much as 85% and shorten the period of regulatory concern by 99.7%.[17] Until 4th generation reactors come online, sometime in the 2040s or 2050s, long-term strategies such as those developed by the U.S. are regarded as reasonable in this context. However, in countries like the ROK, the shortage of domestic spent nuclear fuel storage is becoming a serious problem. For instance, the spent fuel pools at the Kori nuclear power plant (NPP) will be full by 2016 and it is estimated that all at-

[13] "Progress report of Radioactive Wastes WG." Ministry of Economy, Trade and Industry (METI), Japan, May, 2014.
[14] "Managing Spent Fuel from Nuclear Power Reactors."International Panel on Fissile Materials. 2011.
[15] Korea Radioactive Waste Agency got the operation approval of Gyeongju nuclear waste disposal facility, covering low and mid-level radioactive waste, from the Korean Regulatory Authority in Dec. 2014. Yonhap News "Gyeongju nuclear waste disposal facility was approved to operate" Dec. 2014.
http://japanese.yonhapnews.co.kr/Politics2/2014/12/11/0900000000AJP20141211003800882.HTML
[16] "Korea's final nuclear waste disposal site will operate by 2055." The Hankyoreh. November 2014.
http://japan.hani.co.kr/arti/politics/18828.html
[17] "References for advisory committee for nuclear energy policy". METI . p. 55. 2014
http://www.meti.go.jp/committee/sougouenergy/denkijigyou/genshiryoku/pdf/001_s01_00.pdf

reactor spent fuel storage in the ROK will be full by 2024.[18, 19] Even if the Korean government is able to drastically increase on-site dry cask storage, the ROK will have to establish interim spent fuel storage before technical innovation to significantly reduce spent fuel quantities is expected in the mid-21st century. Moreover, Korea has limited reprocessing options because of the 1992 Joint Declaration agreement with the Democratic People's Republic of Korea (DPRK) which prohibits both countries from constructing and operating such facilities.[20] The U.S.-ROK 123 agreement on nuclear energy cooperation also placed heavy restrictions on reprocessing in the ROK due to concerns about separated plutonium. However, since the agreement was recently revised on April 22, 2015[21], this may change. At the very least, the agreement's modifications will allow for continued research into pyroprocessing, which is expected to significantly reduce the amount of waste produced by nuclear power plants (NPPs). That said, pyroprocessing technology will not be able to reduce the ROK's existing spent nuclear fuel stockpile from light water reactors, which support the majority of Korea's domestic nuclear energy program. Other options, such as geological repositories, will still have to be considered.

In Japan, options for spent nuclear fuel management still exist, despite the postponement of commercial operation at the Rokkasho reprocessing facility. On-site interim dry storage is still available, and the Japanese government recently announced a further increase in on-site dry cask storage facilities. Japan is also exploring its options with respect to geological repositories, though it will likely be a decades-long process.

2.3. Take-back Programs

The concept of a take-back program of spent nuclear fuel has a long history. The former Soviet Union, which established a large number of nuclear power plants on its own territory and throughout Eastern Europe, accepted spent fuel from its allies during the Cold War era.[22] The U.S. Department of Energy also engaged in a program to take back spent fuel from research reactors in many countries. As the Nuclear Renaissance grew in the early 2000s, Russia restored the concept of a take-back program to attract new customers to its nuclear energy industry. With one of the few commercial reprocessing capabilities in the world, Russia is one of the only countries to have arranged domestic regulations for acceptance of spent nuclear fuel from

[18] Kang, Jungmin "The ROK's Nuclear Energy Development and Spent Fuel Management Plans" http://nautilus.org/napsnet/napsnet-special-reports/the-roks-nuclear-energy-development-and-spent-fuel-management-plans/, 2014

[19] Einhorn, Robert "U.S.-ROK Civil Nuclear Cooperation Agreement: Overcoming the Impasse" Brookings Institute, 2013

[20] According to Article 3 of the Joint Declaration of South and North Korea on the denuclearization of the Korean peninsula in 1992, South Korea must not possess reprocessing capabilities. "Article3. South and North Korea shall not possess nuclear reprocessing and uranium enrichment facilities."

[21] "U.S. and South Korea Reach Revised Nuclear Deal." New York Times. http://www.nytimes.com/2015/04/23/world/asia/us-and-south-korea-reach-revised-nuclear-deal.html?_r=0.

[22] Spent fuel from the VVER-440 type light water reactors in Finland, Hungary, Bulgaria and Slovakia was shipped to the reprocessing plant in the Soviet Union and was actually reprocessed. Bulgaria and Ukraine even now ships their spent fuel to Russia for reprocessing.

other countries. For instance, Iran signed a nuclear cooperation agreement with Rosatom that included a take-back program for facilities such as the Bushehr nuclear power plant.[23,24] Turkey has also considered the take-back program for its Akkuyu nuclear power plant, which will also use Russian technology. [25]

Despite the relative appeal of a take-back concept, some critics cast doubt on the feasibility of Russia's efforts with respect to both technology and finance. Such a program likely entails enormous costs and will require state-of-the-art reprocessing capabilities. Many emerging nuclear energy countries also wish to avoid an over-dependence on Russia for their energy security given recent crises with, for instance, the supply of natural gas to Europe. Nonetheless, one of the significant benefits of a take-back program is that it allows participating countries to reduce their burden of domestic spent fuel management.

China is one of the only potential take-back program providers. While it has not officially announced an interest in developing such an effort, China is one of few countries with the capabilities to provide one, including: 1. Plans for reprocessing,[26] 2. Various locations with appropriate geological host rock formations for a repository, 3. Government leadership, and 4. The ability to export nuclear facility technology.

2.4. Third Party Option

The concept of sending waste to a third party country is another spent fuel option that has been seriously considered, mainly due to its scientific and commercial advantages. Interim storage or repository sites must satisfy various technical requirements that address geological stability, seismic and environmental risks, and protection of local populations, transportation, and infrastructure. If interim storage or repositories were to be established in a third party country, the total cost of spent fuel management could decrease compared to other methods such as national disposal. However, no official plan has been developed because of political opposition in host countries and communities. In this regard, technical and even economic incentives may not be powerful enough for countries to accept spent fuel from abroad. For example, the Pangea project in the 1990s and proposed site in Mongolia in 2011 both failed because of local political opposition.

As the IAEA has noted,[27] however, a country with no significant quantities of its own wastes, but

[23] Anatoly S. Diyakov "The nuclear "renaissance" & preventing the spread of enrichment & reprocessing technologies: a Russian view", 2010.

[24] World Nuclear Association "Nuclear Power in Iran" (Updated April 2015) http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/Iran/

[25] ROSATOM "Akkuyu Nuclear Power Plant – the first NPP plant configured on BOO principles", 2013

[26] Zhang, Hui. "On China's Commercial Reprocessing Policy." Managing the Atom Project. Kennedy School of Government, Harvard University. http://belfercenter.ksg.harvard.edu/files/On-China-Commercial-Reprocessing-Policy.pdf

[27] "Developing multinational radioactive waste repositories: Infrastructural framework and scenarios of cooperation". IAEA-TECDOC-1413, 2004.

with especially suitable conditions for disposal, could offer to host a repository for commercial reasons. For example, countries such as Kazakhstan with vast amounts of vacant territory may consider hosting interim storage or geological repositories. Areas with vacant contaminated land contaminated from nuclear research, accidents or military testing have also been considered as possible sites hosted by third party countries. As of today, though, none of these options have come to fruition.

3. Options for Multilateral Spent Nuclear Fuel Management

Due to some of the recognized challenges with domestic disposal, take back programs, and third party options, multilateral spent fuel management facilities have been considered. As previously noted, the concept has been around since the 1970s as a way to help address both disposal and proliferation concerns. Three potential scenarios have been considered.[28] One is the so-called "Add-On" scenario whereby existing national repositories allow for the disposal of waste from other countries. Another is the so-called "Cooperation" scenario in which several countries establish and operate joint facilities. The third option is the so-called "international or supranational" scenario in which the international community, led by the IAEA, establishes brand new joint facilities, implementing international control and supervision.

In any of these scenarios, a multilateral spent nuclear fuel management facility would need to include the design, development, and construction of repositories or interim storage facilities, the acceptance of spent fuel from multiple countries, joint operation, and implementation of international nuclear safeguards. Therefore, some experts believe that the "Add-On" scenario is the most feasible option. However, no plan for such facilities has yet been developed due to recent challenges with identifying benefits, issues with transportation and liability, and opposition from local communities.

4. Multilateral Spent Nuclear Fuel Management: Benefits, Challenges, Impacts, and Feasibilities

4.1 Benefits

Multilateral spent fuel management for emerging nuclear energy countries provides several benefits. First, assuming the availability of appropriate resources, such an initiative has potential to reduce risks associated with safety, nonproliferation and security of nuclear materials. Second, geological repositories or off-site permanent storage are arguably better than on-site interim storage facilities as they provide a more long-term solution and potentially better safety and security.

Another major benefit of multilateral spent nuclear fuel management is that it could help address potential proliferation risks associated with reprocessing. For example, spent fuel management is often a motivation for reprocessing. In the ROK, for instance, research on

[28] Ibid.

pyroprocessing has increased as it is believed that this technology will contribute to spent fuel management via the reduction in the quantity of spent fuel produced in the future. However, concerns about Pu bi-product from pyroprocessing make it a sensitive topic. In particular cases in which the international community disagrees with a certain country's national disposal efforts from the viewpoint of nonproliferation or security, multilateral spent nuclear fuel management may provide an alternative.

A joint multilateral effort could also help with the advancement of nuclear energy development as it could be more economically competitive than national disposal. With increased back-end options, the risks associated with nuclear energy could be reduced, which could also impact costs. Stable and reasonably priced nuclear energy could therefore aid economic growth and political stability.

4.2 Challenges

Challenges with the development and implementation of multilateral spent fuel management and nonproliferation have changed dramatically over the past 20 to 30 years due to rapidly evolving geopolitical, economic, and energy developments. For instance, during the latter half of the 20th century, there were fewer concerns about spent fuel management, nuclear safety and nuclear security as there were a limited number of nuclear energy user countries. In addition, the nonproliferation efforts of today would not have been considered an effective approach to nuclear deterrence. In those days, providing a nuclear umbrella from the U.S. or the Soviet Union was more effective in preventing non-nuclear weapons states (NNWS) from developing nuclear weapon technologies. Today, emerging nuclear energy countries want the technology, the capability and, most importantly, do not want their rights under Article IV[29] of the NPT to be restricted. In other words, they do not want to be limited in their ability to enrich and reprocess on their own soil, thus creating a significant nonproliferation dilemma. From their perspective, multilateral spent fuel management could restrict opportunities for reprocessing.

Another significant challenge is the acceptance of spent fuel from other countries. Russia, France and the U.K. are the only countries that have made efforts to accept spent fuel from partner countries for reprocessing. Officially, only Russia does not have to return high-level radioactive waste to the user countries.[30] Prior to 1976, France and the U.K. were not required to return waste to partner countries such as Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, and Belgium. Today, however, waste return is a requirement.[31]

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[29] State Article IV here on right to peaceful use. "Article IV, 1. Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II of this Treaty."

[30] According to International Panel on Fissile Materials "Managing Spent Fuel from Nuclear Power Reactors" (2011), Russia amended their law in 2001 which made it possible for Russia to import spent fuel from other countries for reprocessing. While the Russian law still prohibits the import of radioactive waste for permanent disposal, the government can decide whether or not to return reprocessed waste to the countries which exported it to Russia.

[31] "Developing multinational radioactive waste repositories: Infrastructural framework and scenarios of

From a proliferation perspective, multilateral spent fuel management may not have strong enough benefits to prevent determined countries from developing nuclear weapons. Moreover, such efforts would have to be voluntary rather than mandatory under the NPT, making them even more challenging to implement.

4.3 Impacts

The impact of a multilateral spent nuclear fuel management plan could be felt most prominently in the Asia Pacific region. With economic development and demand for energy accelerating simultaneously, countries may find that the challenges with domestic management of their spent nuclear fuel are not worth the cost. Moreover, whichever country agrees to host a multilateral facility stands to gain significant economic benefits. Below, we consider East and Southeast Asia, including Vietnam and the Korean Peninsula, and other regions, specifically.

East and Southeast Asia consist of both advanced and emerging nuclear energy states, all of which will need some form of spent fuel management within three years of start-up of any nuclear reactor. Though China and Japan both have plans to reprocess,[32] they are seriously considering interim-dry storage and domestic disposal via geological repositories. The ROK and Chinese Taipei have operated nuclear power plants since the 1970s and are facing non-trivial challenges with how to manage their spent fuel. Vietnam is planning to build nuclear power plants and will become the first nuclear energy user in South East Asia. That said, Vietnam has yet to establish a long-term spent fuel management plan. In addition, other countries such as Thailand, Indonesia, the Philippines, Myanmar, and Malaysia have expressed interest in nuclear energy. Some even already have research reactors. Thus, given the diverse landscape of both advanced and emerging nuclear energy states in East and Southeast Asia, a multilateral spent fuel management system may be an important, useful option.

As mentioned above, Vietnam is an crucial test case. Though it plans to establish 14 nuclear power plants by 2030,[33] an official plan for spent fuel management does not currently exist. A multilateral spent fuel management system could help Vietnam significantly. And since it has tempered concerns about proliferation by not expressing an interest in reprocessing and agreeing to strong nonproliferation commitments under its 123 agreement with the U.S., Vietnam stands to serve as a model for emerging nuclear energy states.

On the Korean Peninsula, one of the most significant challenges is the DPRK's nuclear program. One of the benefits of a multilateral spent fuel management system is that it could help

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cooperation" IAEA-TECDOC-1413, 2004.

[32] Zhang, Hui. "On China's Commercial Reprocessing Policy." Managing the Atom Project. Kennedy School of Government, Harvard University. http://belfercenter.ksg.harvard.edu/files/On-China-Commercial-Reprocessing-Policy.pdf

[33] "Nuclear Power in Vietnam". World Nuclear Association. (Updated April 2015). http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/Vietnam/

encourage a normalization of tensions. For example, during the negotiations associated with Agreed Framework between the U.S. and the DPRK in 1994, handling of existing spent fuel was an important discussion topic. Should the DPRK consent to denuclearization in the future, a multilateral spent fuel management facility could provide the alternative to permanent disposal or reprocessing on DPRK territory. In addition, the ROK could benefit hugely from a multilateral storage facility in the event its national interim storage plans are delayed.

In other regions, multilateral spent nuclear fuel management could also reduce the proliferation risks in South Asia and the Middle East. For instance, Turkey, the UAE, Jordan, Saudi Arabia and Bangladesh have plans to establish nuclear power programs. With the exception of the UAE, these countries do not want to consent to the so-called "Gold Standard" and give up their rights to enrich and reprocess. A multilateral option could help address this challenge by reducing motivations for reprocessing.

4.4. Feasibility

Since the turn of the 21st century, the Nuclear Renaissance and the expansion of interest in nuclear energy development has highlighted the importance and potential necessity for a multilateral spent nuclear fuel management system. Such an initiative will require time, research, political will and resources in order to become feasible. For emerging nuclear energy countries, it will likely be at least 10 years before spent fuel management becomes a serious problem. For example, in the ROK, it took 6 years from the start of NPP commercial operation to when discussions on geological repositories began. In addition, it took 12 years to select Anmyeondo Island[34] as a first possible site before the Wolsong LILW facility came into operation in 2010. Thus it is likely that a multilateral spent fuel management plan will take even longer to develop and implement.

Unfortunately, with the exception of Finland, which expects to begin operations of its Onkalo repository around 2020, national geological repositories are only in the planning stages. From a historical perspective, Finland used to send its spent fuel back to the former Soviet Union, the originator of its nuclear infrastructure and technology. However, following the collapse of the Soviet Union and the end of the Cold War, Finland joined the European Union (EU) and had to manage its spent fuel domestically. In 2001, Finland officially decided that a geological repository would be established in Olkiluoto on the west coast of Finland and exploration for site selection and the licensing process began.

Sweden is also on its way to beginning the construction of a geological repository at Forksmark, approximately 140 km northeast of Stockholm. The Swedish Nuclear Fuel and Waste Management Company (SKB), which was established in part for the development of a

[34] The Ministry of Science and Technology, Korea (MOST) and the Korea Atomic Energy Research Institute (KAERI) selected Anmyundo on the west coast as a potential site for low and intermediate level waste disposal, describing it as a second Atomic Energy Research Facility in 1990. Song, Hyun Boo "The discussions associated with the site selection of radioactive waste disposal facilities in Korea" 2006

repository, selected the site in Forsmark and is applying for a construction license. In France, the Agence Nationale pour la Gestion des Dechets Radioactifs (ANDRA) is investigating a site near the village of Bure. While these European countries are further along in the process than others,[35] they have not officially announced an interest in accepting spent fuel from outside their borders. Considering the relationships between governments and host communities and the length of time required for site selection, it will be very difficult for them to accept spent fuel other than their own.

The U.S. could also provide feasibility options for a multilateral spent fuel management facility as a leader in the nuclear nonproliferation, safety and security field. For instance, if the U.S. were to accept spent fuel from emerging nuclear energy countries using existing or new facilities, such facilities could become platforms for future multilateral spent nuclear fuel management efforts. In fact, in some exceptional cases, the U.S. has agreed to repatriate U.S.-origin spent fuel for research, nonproliferation or security reasons.[36] And if the U.S. ever considers a re-start of operations at Yucca Mountain, it could find itself in a similar situation as Sweden and Finland.

Take-back programs could create feasibility challenges as states interested in such efforts will also likely be interested in multilateral spent fuel management. With respect to a timeframe, however, take-back programs are more likely to come to fruition before a multilateral spent fuel management facility is developed. Therefore, if take-back programs begin to dominate the market, multilateral spent fuel management facilities could struggle to survive. Nonetheless, even if Russia and/or China were to implement robust take-back programs, they will probably not be able to cover all emerging nuclear energy countries. If so, multilateral efforts will be an important option. Another challenge with take-back programs is that states who agree to use them will probably be less likely or able to select and implement domestic disposal programs independently for contractual reasons. Regardless of which states may or may not benefit from take-back programs, future prospects for such efforts will become clear within a decade, around the early 2020s. For instance, considering the lack of political and economic stability in Russia, it may consider transitioning its take-back program facilities, such as interim storage, to multilateral spent fuel management facilities in the early 2020s.

While many of the feasibility challenges facing the establishment of multilateral spent fuel management facilities are significant, one thing is still clear: prospects of technical innovation are unknown. Though 4th generation reactors, including Small Modular Reactors (SMR's), will theoretically come into operation in the 2040s or 2050s and could significantly reduce the amount of spent nuclear fuel produced per reactor, options for exploring what to do with the

[35] "References for advisory committee for nuclear radioactive waste disposal." METI. P.21 2014 http://www.meti.go.jp/committee/sougouenergy/denkijigyou/houshasei_haikibutsu/pdf/25_01_02_00.pdf

[36] "Developing multinational radioactive waste repositories: Infrastructural framework and scenarios of cooperation" IAEA-TECDOC-1413, 2004

material in the interim decades should be explored. Multilateral spent fuel management facilities should be considered one option.

5. Conclusion and Recommendations

The advent of the Nuclear Renaissance at the beginning of the 21st century has highlighted the need for multilateral spent nuclear fuel management. Such an effort has the potential to reduce risks related to nuclear safety, security and nonproliferation and to contribute to political and economic stability in the Asia Pacific region. However, it will take time to overcome some of the major challenges to establish such facilities. Game changers are the spread of take-back programs and the technical innovation for dealing with spent nuclear fuel.

The international community should continue to consider and prepare for multilateral spent fuel management as a promising option that could provide economic, energy, and nonproliferation benefits. More research and investigation into this option should be carried out before the early 2020s, however, when prospects for take-back programs will be clear.

In particular, regional or international communities should try to reach consensus on how to deal with spent fuel from emerging countries, as Russia's take-back program will not be capable of addressing the entire challenge. There may be options, including: 1.) A Chinese take back program for emerging nuclear energy states; 2.) Cooperation with Russia and transitioning Russia's take-back program to a multilateral spent fuel management program; 3.) Providing multilateral spent fuel management in the U.S. or Europe which are relatively far along in the process.

From the perspective of many emerging and advanced nuclear energy countries, only the U.S. can provide leadership on this issue. The U.S. is one of few countries that would likely cooperate with Russia or provide a viable facility. If the U.S. were to reach an agreement with Russia in the future, other governments such as Japan and Korea would likely help support the initiative financially. The U.S. should demonstrate similar initiative and leadership as it did in 2005 with efforts such as GNEP.

Finally, it will be important for expert-level international forums such as the OECD/NEA, IFNEC, ARIUS, and the ERDO working group to continue discussions and reach a consensus on next steps. Further analysis and recommendations on concepts such as an international spent fuel consortium overseen by the IAEA should be pursued.

In the interim, states considering the development of domestic geological repository programs should continue to move forward. Such facilities could hold promise of becoming platforms for future multilateral spent nuclear fuel management facilities. These countries also have a unique opportunity to provide leadership for the next generation in the peaceful use of nuclear energy.

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