REPORT

Workshop on Approaches to Financing a Multinational Repository

Sponsored by

The Reliable Nuclear Fuel Services Working Group (RNFSWG)

Sean Tyson and Tomaž Žagar, Co-chairs

11 December 2018

OECD Conference Centre
Paris, France

IFNEC
INTERNATIONAL FRAMEWORK FOR NUCLEAR ENERGY COOPERATION

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Foreword

International Framework for Nuclear Energy Cooperation (IFNEC)

IFNEC provides a forum for cooperation among participating states to explore mutually beneficial approaches to ensure that the use of nuclear energy for peaceful purposes proceeds in a manner which is efficient and meets the highest standards of safety, security and non-proliferation.

The membership of IFNEC includes 34 participant countries, 31 observer countries and 4 observer organizations.

IFNEC is governed by a Steering Group that reports to an Executive Committee. The Reliable Nuclear Fuel Services Working Group (RNFSWG) reports to the Steering Group.

Reliable Nuclear Fuel Services Working Group (RNFSWG)

The RNFSWG membership is open to all IFNEC members and currently includes 22 active members, representing 19 countries and 3 organizations: Argentina, Armenia, Australia, Bahrain, Bulgaria, Canada, the People's Republic of China, France, Italy, Hungary, Japan, Jordan, Korea, the Russian Federation, Mexico, Singapore, Slovenia, Ukraine, the United States, the International Atomic Energy Agency (IAEA), the OECD Nuclear Energy Agency (NEA), and Euratom.

The multinational repository concept has been part of the IFNEC agenda since 2009. The term "multinational repository" refers to arrangements where customer countries enter into agreements to have their spent fuel disposed of in a country that has disposal capability, the service provider country. Since 2014, the RNFSWG has largely focused on the back end of the nuclear fuel cycle, particularly disposal and the multinational repository concept.

In 2016, the working group published a paper titled "Practical Considerations to Begin Resolving the Final Spent Fuel Disposal Pathway for Countries with Small Nuclear Programs". From a country perspective, the consideration and support for the multinational repository concept are reflected by the adoption of the "dual track approach" to the back end. This approach involves progress in the development of a national repository program while at the same time supporting the development of multinational repository opportunities. This paper is available on the IFNEC

website[1] and has contributed to further understanding within the IFNEC community of the dual track approach.

The current topic of report, financing a multinational repository, was selected by the RNFSWG members as a subject for the working group to explore.

Multinational geological repository (MNR)

A geological repository is recognized worldwide as the reference solution for the disposal of spent nuclear fuel, and high-level radioactive waste. A geological repository is an expensive undertaking with high fixed costs that are largely independent of the size of the repository. This makes a multinational geological repository (MNR) an interesting option for reducing overall costs for disposal and providing countries with small spent fuel inventories with options for addressing the challenges presented by the back end of the fuel cycle.

1. www.ifnec.org/ifnec/jcms/g_10234/2016-ifnec-practical-considerations-to-begin-resolving-the-final-spent-fuel-disposal-pathway-for-countries-with-small-nuclear-programs.

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Chapter 1. **Introduction**

This report summarizes the workshop on "Approaches to Financing a Multinational Repository" that was held at the OECD Conference Centre in Paris, France, on 11 December 2018. The purpose of the report is to make the workshop and the outcomes of the workshop accessible to all members, especially those who were unable to attend. The Reliable Nuclear Fuel Services Working Group (RNFSWG) organized and sponsored the workshop and the conduct of the event was supported by the International Framework for Nuclear Energy Cooperation (IFNEC) Technical Secretariat.[2]

The workshop morning sessions began by providing background information on previously identified approaches to financing and included presentations describing the general characteristics relevant to financing a multinational repository project: project phases and durations, expected funding allocations across the phases, estimates of overall project costs, and financing risks. Chapter 2 of the report summarizes the key information from these presentations.

These sessions were followed by presentations by the International Atomic Energy Agency (IAEA) and a number of countries on planning related to financing, past projects and lessons learned. Abbreviated summaries of these presentations can be found in Chapter 4 of the report.

Having laid the foundation of past experiences and identifying the finance related aspects of a repository project, the workshop's afternoon sessions, addressed in Chapter 3 of the report, proceeded with presentations of unique financing approaches independently developed by invited groups of experts. The approaches were based on a set of general assumptions regarding the project to be financed. The approaches presented were diverse, creative, and succeeded in creating renewed interest, opening the topic to further inquiry in the future.

All of the workshop presentations can be found on the IFNEC website.[3] If there is interest in a further understanding of the financing approaches summarized, the reader can review the specific presentations and is also encouraged to contact any of the authors at the email address noted in their presentations.

2. On the day before the workshop, 10 December, the French National Radioactive Waste Management Agency, ANDRA, hosted a technical visit for members of the RNFSWG to their Meuse/Haute-Marne underground laboratory site, the Cigéo Project.

3. www.ifnec.org/ifnec/jcms/g_11435/rnfswg-mnr-financing-workshop.

Chapter 2. **Defining a multinational geological repository project**

The multinational geological repository (MNR) concept provides a shared solution to the challenges of spent fuel and high-level radioactive waste disposal. The concept involves a service provider country developing a geological repository and accepting spent fuel and high-level radioactive waste from several customer countries. The concept includes arrangements involving the formation of a partnership organization where the repository is built in one of the partner countries for use of the partner members, and also the case where a country decides to develop a multinational repository to provide a fee-based disposal service to customer countries. Both approaches share many of the same challenges, such as the need for financing.

Although financing is an issue shared by all repository projects, an MNR project presents a unique case regarding issues associated with the sources of funds, timing of revenues and expenditures, and risk allocation. Interested international organizations are approaching this issue from diverse perspectives. These activities include work by different intergovernmental and international organizations (i.e. International Atomic Energy Agency [IAEA], Nuclear Energy Agency [NEA], and World Nuclear Association [WNA]).

The phases and spending profiles for a geological repository project

Alan Brownstein, Consultant

Siting and Licensing – 20 years – 15% of total costs

Construction – 15 years – 35% of total costs

Operations – 40 years – 45% of total costs

Decommissioning, closure, long-term monitoring – 75 years – 5% of total costs

A 35-year period from initiation to commencing operations is beyond that of most construction projects. Siting and licensing phases do not require large upfront investments. As much as 50% of the total costs are incurred before services can be provided. Financing a MNR will be more complex than a national repository

However, if one were to assume an evolution from a first-of-a-kind facility to a situation where national repositories have been successfully developed and countries were strongly supportive and committed to a MNR, then initial time frames could be significantly reduced:

- siting and licensing – 13 years – 15% of total costs;
- construction – 10 years – 35% of total costs.

Under these assumptions, the time from project initiation to waste acceptance could be reduced from 40+ years to 25 years or even slightly less, and more importantly from a financing perspective:

- **The first 13-15 years are not cost intensive** (about 15% of total project costs might be funded without the need for outside financing).
- **The challenge then becomes financing a project for ten years** before waste acceptance begins and revenues are generated.

The costs of geological disposal

Neil Chapman, Vice President of Arius Association

Cost estimates for geological disposal have been made by most national programs. Guidance for estimating costs has been published by the NEA, EDRAM, IAEA, and some nations have formal guidance on costing major national infrastructure projects extending over long periods of time.

Geological repository fixed and variable cost components

Fixed

- site selection and permitting;
- surface handling facilities;
- transport infrastructure;
- access shafts/tunnels;
- access closure and sealing;
- environmental monitoring.

Variable

- emplacement tunnels, vaults, boreholes;
- disposal operations;
- encapsulation of spent fuel.

A SAPIERR[4] study of disposal costs using 2006 data concluded:

- Total disposal costs for "large" inventory (26 000 tHM [spent fuel]; 360 cubic metres high-level waste; 31 000 cubic metres intermediate-level waste) would cost approximately EUR 10 billion.
- The overall impact of a 14 country shared repository rather than numerous national repositories would provide a EUR 15-25 billion saving to Europe.

So, what *do we know today about what* geological disposal costs?

- spent fuel: around USD 1 million per tonne:
  - less for a larger program, more for a small program.
- overall cost for a small national repository program: around USD 2-5 billion;
- overall cost for a large national repository program: from around USD 15 to as much as USD 50 billion;
- cost saving for a small national program from sharing in a MNR: at least 30-50% of " standalone" cost;
- a specific example of saving from possible sharing:
  - Slovenia-Croatia: shared or separate near-surface repositories;
  - sharing increases overall investment costs by only 13% compared with 100% for separate facilities.

USD 1 million per tonne is a very affordable spent fuel disposal cost since:

- 1 tonne (tHM) produces around 440 million kWh of electricity (55 000 MWd/t thermal at 33% efficiency);
- selling price of electricity (in France for example) is USD 0.2/kWh, which produces *revenues from 1 tHM of about USD 88 million*;
- electricity production costs are about USD 0.025/kWh = USD 11 million;
- price for a disposal service in a commercial multinational facility might be perhaps USD 1.5 million or more.

Providing a conclusion that the total of production costs and possible disposal service prices would be a small fraction of revenues from the sale of electricity.

4. SAPIERR was a two-phase study of the technical, legal, economic and societal aspects of potential shared storage and disposal of radioactive wastes in Europe. It involved 14 countries, was concluded in 2009 and was funded by the European Commission. The SAPIERR-2 reports are available at: www.erdo-wg.com/erdo_documentation.html.

Project risks in financing a multinational repository

Charles McCombie, President of Arius Association

The project risks in implementing an MNR can be categorized as: technical, institutional, socio-political and financial. In finance, risk is the chance that the return achieved on an investment will be different from that expected; it also takes into account the possibility of losing some or all of the original investment.

Risks can come from financial markets, project failures, legal liabilities, regulatory delays, political upheavals, accidents, natural causes and disasters, or events of uncertain or unpredictable root-cause.

Key financial risks to the MNR service provider

- insufficient customer base (present or future);
- undercut by MNR competition;
- ensuring liquidity up to disposal operations;
- delays due to public/political opposition;
- liability payments due to operational malfunctions;
- national policy changes to exclude import;
- long-term liabilities;
- currency exchange rates.

Key financial risks to the MNR service user

- upfront funding (e.g. pre-payments; storage fees) loss due to project failure (technical or political);
- long-term contracts exclude potential future competing MNR offers;
- service provider or his government withdraws services;
- national policy changes to exclude export;
- service provider insists on shared liabilities;
- currency exchange rates.

- Most project risks in a repository development are similar whether one considers national or multinational implementation – the greatest exceptions are political and financial risks.
- For an MNR, financial risks and mitigation measures will differ between sharing concepts and commercial service provider approaches.
- Analysis of risks, their impact and the potential mitigation measures should be an integral part of any MNR proposal.
- Given the long timescales of an MNR project, the allocation of risks to project partners may differ throughout its development and implementation.
- A robust, sustainable financing mechanism is essential for success of a service provider initiative.
- This has proven to be the stumbling block is some past proposals – we need new ideas.

Chapter 3. Approaches to financing a multinational repository project

Introduction and assumptions

Four groups of experts in the fields of nuclear projects and financing were asked to work independently and develop their creative approach to financing a multinational repository project. As a common basis for developing their approaches, the groups were provided with the presentations from Chapter 2 describing key attributes of a multinational geological repository (MNR) project, and also the following assumptions about the hypothetical project to be financed:

1. Issues of public acceptance, the enduring nature of the national commitments of the customers or service provider are satisfactorily resolved and all necessary legal authorities are in place.
2. Technologies associated with transportation, handling, storage, and disposal are fully developed.
3. The potential service provider is a state-owned enterprise with the mission of developing the capability to offer a spent fuel/high-level waste disposal service to customer countries in return for the payment of a fee.
4. The state-owned enterprise has access to minimal state funds, but not enough to develop the disposal capability (site and construct a repository).
5. If the development of a multinational repository is to happen, the bulk of the costs will need to be financed.
6. The state-owned enterprise is interested in identifying approaches to financing that could include either debt or equity, would expect to include the participation of the customer countries and perhaps also banks and other lenders and investors.
7. The customer countries are assumed to have the funds in dedicated national accounts necessary to pay whatever reasonable fee that is set by the service provider.
8. There are a sufficient number of customers to justify the service being provided.

Each group developed and presented basic conceptual descriptions of their financing approaches which are summarized in the following pages. The full descriptions can be found in the presentations posted on the International Framework for Nuclear Energy Cooperation (IFNEC) website.

The four approaches in a nutshell

1. **It is clearly challenging to finance one MNR… but may be "easier" to finance several** – Countries from different regions of the world interested in developing an MNR create a consortium. The consortium will pursue the sequential development of several MNRs.
2. **Government sells shares in the repository project with return on investment coming from fees collected during operation** – A country sponsoring the development of a geologic repository project through a government agency or state-owned corporation would enter into multilateral agreements with other countries for the sale of equity shares in the project.
3. **Staged financing beginning with selling interim storage** – A staged repository project would consist of an initial phase of developing and operating a spent fuel storage facility (dry storage) with a portion of revenue allocated to development of a co-located permanent repository.
4. **Two approaches: government developing project with and without customer investment** – This presentation identified two approaches to financing. In the first the government in the service provider country develops the project and provides initial financing through initial operation (waste emplacement), at which point an exit strategy (in part) could be utilized. The second focuses on the early financial participation of the customers through the purchase of shares in the repository project, with finances managed in an arms-length fund.

Approach 1: It is clearly challenging to finance one MNR … but may be "easier" to finance several

George Borovas, Global Head of Shearman & Sterling's Nuclear Group

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The first MNR (MNR-1) will have the largest risk in terms of siting, licensing and construction, however all participating governments would agree to share this upfront risk. Private funding will be secured as commercial operation begin.

Due to a harmonized development approach for each project, and replication of technical design to the extent possible, risk for MNR-2, MNR-3, MNR-4, will be decreasing. Siting, licensing and construction times will also decrease, all resulting in additional opportunities for outside financing.

The financing approach is described in the following steps:

1. Consortium lead countries work with countries around the world that are interested in developing an MNR to identify multiple project candidates and secure commitments.
2. The participants create a project company MNR.INC with equal shares and sharing of costs of financing for the siting, licensing and construction of MNR-1. MNR.INC takes the completion risk (i.e. all governments share the risk).
3. The initial objective might be to have one participant in Europe, one in Asia, one in Australia, one in Africa and one in the Americas.
4. Participants would agree on a harmonized site identification, investigation, licensing, construction, operational and closure model to be pursued in each country.
5. All agree on a country that will go first for the development of MNR-1 with the full support of the consortium.
6. Export Credit Agency (ECA) and ECA-covered commercial bank financing support would be provided by nations exporting equipment and services for the construction of MNR-1.
7. All IP developed for MNR-1 belongs to MNR.INC and is licensed to MNR-1.
8. At commissioning, MNR-1, is refinanced with private debt and equity with host and customer government backstop for uninsurable risks and an annual royalty payment to MNR.INC for use of intellectual property.
9. MNR-1 uses the collection of disposal fees during the operations phase from the dedicated national accounts of customer countries to repay its debt and equity holders, setting aside on an ongoing basis in a dedicated account the funds required for closure activities.
10. Upon refinancing of MNR-1, MNR.INC uses its funds for the same process for MNR-2, MNR-3, MNR-4, etc.
11. One option to consider is whether the government where MNR-1 is being developed has an option to withdraw from MNR.INC with the other consortium members purchasing its equity in equal shares. This could be the upside for a country to accept to build the first MNR in its territory even if it has no waste in need of disposal.

Approach 2: Government sells shares in the repository project with return on investment coming from fees collected during operation

Elina Teplinsky, Partner, Nuclear Energy, Pillsbury Winthrop Shaw Pittman LLP

A country sponsoring the development of a geological repository project through a government agency or state-owned corporation would enter into multilateral agreements with other countries for the sale of equity shares in the project. Shares would be sold with funding rounds reflecting the development status of the project. A third party trustee would manage the funds to ensure transparency.

Site selection and licensing details

- Site selection is the responsibility of the service provider government and will include obtaining local and regional support, removing a major element of risk. This would be done using national funds.
- Licensing:
  - With the site selected, the service provider would begin selling shares in the project – some government guarantee likely needed.
    - use of proceeds: licence application and legal costs;
    - approval of licence application could take several years.
  - Completion of licensing will increase interest and mean that project risk will have decreased, increasing the ability to sell shares to finance the project.
- The primary incentive for investor nations during early phases is that early investors will have lower disposal costs than other customers once the project begins operations.
  - If an investor nation later chooses to pursue another disposal strategy, they could recoup their investment by selling their shares in the project to another investor nation.

Construction details

- Estimated to require 35% of total project cost and take 10-20 years to complete.
- A combination of debt and equity will be used to finance construction by:
  - additional funding rounds selling shares;
  - issuance of project bonds;
  - selling rights to advanced-disposal services at a discounted rate;
  - financing by the service provider.
- Financing options will be heavily dependent on the estimated length of construction, confidence of cost estimates, and the perceived overall quality/integrity of the project.

Operations details

- the operations phase will last decades and require approximately 45% of total project costs.
- financed by the service provider selling disposal services in return for a fee:
  - fee will include:
    - project development and financing costs;
    - operational costs;

  - contribution to trust account to cover closure and long-term monitoring;
  - return on investment.
- project shareholders will participate in the return on investment:
  - for shareholders with disposal needs, this could be used to pay for disposal costs.

Closure details

- Decommissioning, closure, and monitoring will take a small percentage of total project costs, could last centuries, and would be funded by a fraction of the proceeds from the sale of disposal services used to establish a long-term trust that will finance this phase.

Additional consideration

Repository may not necessarily need to be located in service provider country. By being able to enter into multilateral agreements, the service provider could explore establishing the facility in another nation interested in locating the facility:

- The advantages to this nation would be economic development and investment resulting from project development.
- Because of the critical nature of local community support, this would increase the options for the service provider to find an acceptable site for the facility.

Approach 3: Staged financing beginning with selling interim storage

Robert Sloan, Senior Research Fellow, Energy Faculty, Tulane Law School
Elise Zoli, Partner, Jones Day

A staged repository project would consist of an initial phase of developing and operating a spent fuel storage facility (dry storage) with a portion of revenue allocated to development of a co-located permanent repository.[5] This approach would be used to attract commercial investor involvement in a step-wise fashion. It would build credibility and experience for nuclear fuel management by phasing out "by and for governments only" and replacing with commercial investment.

Key conceptual elements of an interim storage/repository investment

- An investment structure that depends on participation from spent fuel owners (whether public or private) and de-risks commercial investment.

5. Note that a reviewer of the draft report commented that co-location might not be the preferred approach since the extended time required to site a permanent repository would delay the siting and operation of the interim storage facility

- An interim storage service that provides near-term success and "start-up" capital for the repository.
- A step-wise approach that allows investment at an accessible initial scale and validates the approach, before proceeding with the repository investment.

Summary options, with a focus on blended finance

- Option 1, public/private partnership:
  - The government funds a portion of the project, consisting of the interim storage facility, as well as initial repository development and early operating costs, with additional funding based on reduced returns (e.g. grants and concessionary loans), and risk-control mechanisms (e.g. loan guarantees and insurance).
  - Commercial partners participate, with initially sovereign guaranteed returns that meet market expectations, on the remainder of the project.
  - Because the project includes a well-established cost basis for interim storage, commercial involvement is possible even at the early stages.
- Option 2, fully privatized approach: a major international corporation undertakes the investment and assumes 100% of project risk. This option is not considered viable at this time, but illustrates the benefits of transitioning in Option 3.
- Option 3, a blended approach of the options 1 and 2: government funds or backs/guarantees the development of the interim storage facility and initial years of repository operation, with a subsequent buy-out by commercial investors of the government share.

Public/private partnership, option 1 example

- Interim storage facility: USD 8B in development and operational costs (through year 3), with a right to an additional USD 2B reserve through year 5, funded as follows:
  - government share (40%): USD 4.8B, with a reserve of USD 1.6B;
  - operator share (20%): USD 1.6B, with a reserve of USD 0.4B;
  - commercial investor share (40%): USD 4.8B, with a reserve of USD 0.0B.

Public/private partnership blended approach, option 3 example

- After five years financing allocations to government, operator, and commercial investor convert to all operator and commercial investor allocation.
  - Residual operator share options: 10-40%.

Approach 4: Two approaches: government developing project with and without customer investment

Timothy A. Frazier, Nuclear Economics Consulting Group Affiliate
Edward Kee, CEO & Principal Consultant, Nuclear Economics Consulting Group
Paul Murphy, Managing Director, Management Department, Murphy Energy & Infrastructure Consulting, LLC
Xavier Rollat, Alet Business Services Limited

This presentation identified two approaches to financing. In the first the government in the service provider country develops the project and provides initial financing through initial operation (waste emplacement), at which point an exit strategy (in part) could be utilized. The second focuses on the early financial participation of the customers through the purchase of shares in the repository project, with finances managed in an arms-length fund. In contrast, for the first approach the government leads the overall effort, with its role decreasing over time. In the second, the effort is co-led by the government and one or more customers that take membership interests in the project.

Both approaches start with these basic assumptions:

- The government developing the project will need to provide overall leadership with an underpinning of public and political support, legal and regulatory regimes, and the necessary infrastructure.

  Initial participation, while evidenced by commercial commitments, will rely on government-to-government arrangement that are backstopped by sovereign guarantees.

Approach 1, Project development government as anchor financier

The most likely scenario for this approach would be where there is already a need to develop a high-level waste disposal solution, and the government sees an MNR as an economic opportunity. In this scenario, the government is building and financing an asset with a view to selling parts of it in the future and creating a client-based, "pay as you go" structure to justify the scaling up of capacity.

- initial debt for development and construction would be financed by a loan from the government to the project;
- Export Credit Agency financing to be sourced, as applicable;
- government would assume completion risk (cost overruns, delays);
- government debt would be refinanced after disposal operations begin through customers and/or passive investors (if the economics support such investment).

Rationale for government to develop project:

- infrastructure/economic development to country (and region within country);

- projected revenues from customers;
- option to sell down once facility is in operation:
  - participating countries can become equity holders;
  - private capital is more inclined to provide equity investment in the project (or long-term debt as an alternative to equity investment).
- speed of project development (easier for government to independently develop the project, avoiding the co-ordination needed between multiple participants that could likely slow things down).

Concerns:

- size of equity contributions needed; cost of equity (and, in a worst case scenario, availability of equity);
- contract formation/commitments with customers;
- general capabilities of government to develop the project absent established experience.

Approach 2, Co-investor/customer financing

The likely scenario for this approach would be where the government in the service provider country does not necessarily have to provide a disposal solution for its own high-level waste. In this scenario, the government sets up a group of co-investors (project members) who will develop, finance, and use the storage facility together in the future (allowing for additional participants and investors). This is more like a "classical" investment proposal with an innovative structure to support a new endeavor.

- The project is established by the government with each participating customer purchasing membership shares in the project.
- A fund would be established for initial contributions from customers purchasing membership interests, and subsequently collecting payments and disbursing funds as project milestones are achieved.
- Each membership share would entitle the customer to a specified reserved capacity in the facility, with subsequent usage fees charged as actual material is emplaced.
- Dividends would be returned based on membership interest and level of contributions.
- The project would take on debt through Export Credit Agency financing, as applicable, with debt service and cost overruns paid by the fund, with possible refinancing of debt after commercial operation.
- Risk would be shared pro rata to membership interest.
- Obligations would be backstopped by sovereign guarantees.
- General operating costs would be passed through to the members.

- The fund would be managed by an experienced team of financial experts on an arm's length basis to de-risk the project and protect members' interests.
- Additional/future facility users could buy membership interests, assuming that the facility is sized to accommodate such additional capacity, with such membership interests and usage fees being deposited in the fund (and enhancing the returns of the original members).

Motivations for members:

- reservation of capacity; usage of capacity;
- removal of need for national facility replaced by alternative with reasonable costs;
- overall savings via economies of scale aggregation of memberships.

Chapter 4. **Planning related to financing, past projects/lessons learned**

This session included presentations from the International Atomic Energy Agency (IAEA) and four countries. The following are short summaries of those presentations. Please refer to the slides of the actual presentations, which as noted are included on the International Framework for Nuclear Energy Cooperation (IFNEC) website,[6] for details of the information that was provided.

Costing methods and funding schemes for radioactive waste disposal programs

Stefan Mayer, Team Leader Disposal, Nuclear Energy, IAEA and Phillippe Van Marcke, Radioactive Waste Disposal Specialist, IAEA

A report has been submitted to the IAEA for publication "Costing methods and funding schemes for radioactive waste disposal programs". The objectives of the report are to provide member states guidance on estimating the cost of a disposal program, and establishing funding schemes to cover the cost. The report is expected to be available in 2019.

The Nuclear Waste Management Fund of Finland

Anne Väätäinen, Counsellor of Innovations and Enterprise Financing, Ministry of Economic Affairs and Employment, Finland

The Nuclear Waste Management Fund in Finland currently consists of EUR 2.6 billion. The purpose of the fund is to cover the remaining costs of nuclear waste management and thus provide the means for the management of all nuclear waste generated in Finland. This also includes decommissioning. Producers of nuclear waste are obligated to participate in the fund.

Financing the Finnish final disposal

Mike Pohjonen, Managing Director, Posiva Solutions Oy, Finland

The repository programme of Posiva Solutions has progressed over 40 years and includes the issuance of a construction licence in 2015. Estimates of the costs of final

6. www.ifnec.org/ifnec/jcms/g_11435/rnfswg-mnr-financing-workshop.

disposal of 6 500 tU (3 250 canisters) total EUR 5 250-6 250 million (*editor's note – this is EUR .8-.96 Million per tU and is in the range of the USD 1 Million per tU previously suggested*).

Russian approach to high-level waste and spent fuel management

Anzhelika Khaperskaya, Leading Manager, Spent Nuclear Fuel Management Project Office, State Corporation ROSATOM

The approach Russia uses for high-level waste and spent fuel management relies on reprocessing and recycling and the development of advanced fuel cycles. Russia is developing advance technologies for high-level waste partitioning and minor actinide transmutation. An important benefit of advanced fuel cycles is the significant reduction of the amount and radiotoxicity of high-level waste that requires disposal.

Approach for Japan to high-level waste disposal cost estimation

Katsumoto Yoshimura, Director of Technology Office for Radioactive Waste Management, Ministry of Economy, Trade and Industry, Japan

The chronology of Japan's disposal program was discussed noting that to date no site or host rock has been identified. However, Japan has an elaborated approach to site identification in place, which includes participatory involvement of potential (future) host communities. The nuclear fuel cycle policy relies on reprocessing and mixed oxide fuel fabrication resulting in high-level waste and transuranic waste that will require disposal. Disposal activities are funded by nuclear power operators and reprocessing facility operators making payments to the Nuclear Waste Management Organization of Japan (NUMO), the nuclear waste management organization. The current total estimate for disposal of both high-level waste and transuranic waste is JPY 3 826 billion.

Canada's approach to spent fuel disposal: Financial assurances and costing

Dave McCauley, Director of the Uranium and Radioactive Waste Division, Energy Sector, Natural Resources, Canada

In 2007 the government of Canada selected the Nuclear Waste Management Organization's (NWMO) recommended adaptive phased management approach for spent fuel disposal that involves locating a deep geological repository in a willing host community and in a suitable geological rock formation. NWMO commenced the siting process in 2010. NWMO estimates total disposal project costs at CAD 23 billion (in 2015 dollars) including the full life cycle costs – planning, regulatory review, construction, operations, transportation, monitoring, decommissioning and closure.

Chapter 5. **Furthering the working group agenda**

This workshop was one part of an ongoing agenda of the Reliable Nuclear Fuel Services Working Group to explore back end issues associated with the multinational repository concept that have not received much notable attention.

As noted in the Foreword, the last publication of the working group addressed the important policy option adopted by many countries, the dual track approach. This paper provided practical information on what countries might consider if they choose to support the development of shared solutions to the back end.

The topic of this workshop, alternative approaches to financing a multinational repository, was selected by the members of the Working Group. With the support of a number of members participating on a Planning Committee, a workshop was held with creative inputs from international experts that resulted in the outcomes noted in this report.

The working group will now discuss the most effective ways to build on those outcomes. Possible option to consider include

- further inquiry into financing alternatives;
- creating a Project Development Plan for potential service provider countries to review and inform their decisions;
- approaches to managing the risks associated with financing;
- collaboration with other agencies on related topics;
- further understanding incentives that can offset challenges and barriers.

The Co-chairs will manage this decision process and the implementation of the decisions of the working group. On behalf of the International Framework for Nuclear Energy Cooperation (IFNEC) they express appreciation for the participation of current members of the working group and encourage others interested in the challenges presented by the back end to become members.

Chapter 6. **Workshop epilogue**

The possibility of reaching the summit of Mount Everest was first asserted in 1885. There were many attempts over the next 68 years to do that. The first successful assent was in 1953, and the second only three years later.

Recorded efforts to run a mile in under four minutes go back to the 1700s. The feat was first achieved in May 1954. Two months later competing runners both ran the mile in under four minutes.

These are just two of a myriad of examples of challenges considered to have insurmountable barriers being successfully overcome not just once, but again soon afterward.

Since 1992, when treaties under the Basel Convention became effective, vast quantities of hazardous waste has been safely transported around the world from generator country to disposal service provider country. Much of this waste is arguably more hazardous than spent fuel, and yet qualified service provider facilities are established, commercial agreements are put in place, and the wastes are managed and disposed of economically and by those most capable of doing it safely.

Much has been written about the challenges of developing a multinational geological repository (MNR). Those challenges are all very real, but so is the fact that those challenges can, and perhaps likely will, be overcome. As with the examples above, they will not be overcome by focusing on the difficulties, but rather in the possibilities of achieving success.

The development of an MNR can be considered at least likely at some time in the future. Workshops such as this one that initiate or continue the discussion of possibilities for countries to successfully offer a disposal service contribute to the seemingly insurmountable barriers being overcome. It is possible if such efforts continue that one day countries that generate nuclear power will have options involving shared solutions for addressing the challenges of the back end.

Appendix A. **Workshop agenda**

8:30-9:00 **Registration**

9:00-9:10 **Welcoming remarks**
Sama Bilbao y Leon – Head, Division of Nuclear Technology Development and Economics, NEA

9:10-9:20 **Introduction to the workshop and recent activities of the working group**
Co-chairs Sean Tyson and Tomaž Žagar

9:20-09:35 **Past approaches to financing an MNR and large projects**
Charles McCombie – President of Arius Association, Arius Association and European Repository Development Organisation (ERDO) Working Group

9:35-10:00 **What are the generally understood phases of any geological repository project and what is the spending profile for those phases?**
Alan Brownstein – Consultant

10:00-10:25 **What is the cost of an MNR?**
Neil Chapman – Vice President of Arius Association

10:25-10:50 **What are the risks that will have to be addressed in any financing arrangement for a MNR?**
Charles McCombie – President of Arius Association, Arius Association and ERDO Working Group

10:50-11:10 **Group photo and coffee break**

11:10-12:50 **Planning related to financing, past projects/lessons learned**

11:10-11:30 Costing methods for high-level radioactive waste disposal programmes
Stefan Joerg Mayer – Team Leader Disposal, Nuclear Energy, IAEA

11:30-11:50 Finland's experience
Anne Väätäinen – Counsellor of Innovations and Enterprise Financing, Ministry of Economic Affairs and Employment, Finland
Mika Pohjonen – Managing Director, Posiva Solutions Oy, Finland

11:50-12:10 Russian approach to high-level waste and spent fuel management
Anzhelika Khaperskaya – Leading manager, SNF management Project Office, State Corporation ROSATOM

12:10-12: 30 Approach to high-level waste disposal cost estimation
Katsumoto Yoshimura – Director of Technology Office for Radioactive Waste Management, Ministry of Economy, Trade and Industry, Japan

12:30-12:50 National waste management approach on deep geological spent fuel disposal – costing and financial assurances
Dave McCauley – Director of the Uranium and Radioactive Waste Division. Energy Sector Natural Resources, Canada

12:50-13:50 Lunch hosted by NEA/IFNEC

13:50-15:20 Approaches to Financing an MNR in response to the Hypothetical Scenario

13:50-14:00 Description of Hypothetical Scenario and introduction of panel
Robert Mussler, Consultant

14:00-14:20 *George Borovas – Partner and Head of Nuclear, Shearman and Sterling LLP*

14:20-14:40 *Robert Sloan – Senior Research Fellow, Energy Faculty, Tulane Law School Energy Centre. Elise N. Zoli – Partner. Jones Day*

14:40-15:00 *Elina Teplinsky – Partner, Nuclear Energy, Pillsbury Winthrop Shaw Pittman LLP*

15:00-15:20 *Paul Murphy – Managing Director, Management Department. Murphy Energy & Infrastructure Consulting, LLC. Edward Kee, Xavier Rollat, Ted Fraiser*

15:20-15:35 Coffee break

15:35-17:00 Moderated roundtable discussion to include participation by attendees

George Borovas – Partner and Head of Nuclear, Shearman and Sterling LLP

Alan Brownstein – Consultant

Neil Chapman – Vice President of Arius Association

Charles McCombie – President of Arius Association, Arius Association and ERDO Working Group

Paul Murphy – Managing Director, Management Department, Murphy Energy & Infrastructure Consulting, LLC

Robert Sloan – Senior Research Fellow, Energy Faculty, Tulane Law School Energy Centre

Elina Teplinsky – Partner, Nuclear Energy, Pillsbury Winthrop Shaw Pittman LLP

17:00-17:15 Closing Remarks
Co-chairs Sean Tyson and Tomaž Žagar

Appendix B. **Short biographies of the presenters**

Sama Bilbao y León – Head of Division of Nuclear Technology Development and Economics at the OECD Nuclear Energy Agency (NEA)

In her role at the NEA, she helps provide Member Countries with authoritative studies in support of their energy policy decision-making. Sama has a very diverse professional experience having worked in the nuclear industry (Nuclear Safety Analysis Engineer, Dominion Energy, United States), in academia (Director of Nuclear Engineering Programs and Associate Professor at the Department of Mechanical and Nuclear Engineering, Virginia Commonwealth University [VCU], United States) and in international organisations (Technical Head of Water Cooled Reactors Technology Development Unit, International Atomic Energy Agency [IAEA]). Sama, who is originally from Spain, holds a bachelor's degree in Mechanical Engineering and a Master's degree in Energy Technologies from the Polytechnic University of Madrid; a Master's degree and PhD in nuclear engineering and engineering physics from the University of Wisconsin – Madison; and an MBA from Averett University. Sama's areas of expertise are nuclear thermal hydraulics for both light water reactors and sodium cooled reactors, nuclear reactor design, nuclear safety, energy and environment policy, and complex decision-making.

Sean Tyson – Office of Nuclear Energy, US Department of Energy

Sean Tyson graduated in 1992 from the Monterey Institute of International Studies with a Master's degree in International Policy Studies, with an emphasis on arms control and non-proliferation. He has since served with the United States Department of Energy in a variety of international programs focused on international cooperation on non-proliferation.

In the late 1990s, Mr Tyson provided direct oversight of the cleaning, conditioning and storage activities in Nyongbyon, Democratic People's Republic of Korea under the Agreed Framework between the United States and the Democratic People's Republic of Korea. He then transitioned to the US-Russia Materials Protection, Control and Accounting programme, where he managed activities focused on increasing nuclear materials security at nuclear facilities in Russia. Most recently, Mr Tyson has supported the Office of Nuclear Energy bilateral and multilateral exploration of multinational options for the disposal of spent nuclear fuel and high-level radioactive waste.

Tomaž Žagar – Head of Planning and Control in GEN energija

He received B.Sc. degree in physics from the University of Ljubljana and Ph.D. degree in nuclear engineering from the University of Maribor. He is first generation fellow of World Nuclear University in Idaho, United States and alumni of IEDC – Bled School of Management, Slovenia. Previously, he was appointed Director of the Radioactive Waste Management Agency of Slovenia. He was a researcher at Jožef Stefan Institute in Ljubljana, Slovenia and at Institute for Transuranium Elements in Karlsuhe, Germany. He has been working in the nuclear sector for the past 20 years.

He is a Slovenian representative in the Nuclear Development Committee at the Nuclear Energy Agency in Paris and a member of Council for Nuclear and Radiation Safety at Ministry of Environment of Republic of Slovenia; in addition, he was a member of the Council of the Energy Agency of Slovenia.

He is an author of several papers on nuclear engineering, spent fuel, and radioactive waste management.

Charles McCombie – President of Arius Association, Arius Association and European Repository Development Organisation (ERDO) Working Group

Dr McCombie is an independent strategic and technical advisor to numerous national and international radioactive waste management programmes. For 20 years, he was scientific and technical director of the Swiss national disposal program. For 8 years he served on the US National Research Council's Board on Radioactive Waste Management, latterly as Vice-Chairman. Currently his chief responsibilities are as President of the Arius Association and Secretary of the European Repository Working Group; both organisations focus on enhancing multinational co-operation at the back end of the fuel cycle.

His responsibilities throughout his career have covered reactor safety, performance assessment for disposal, repository engineering and geological investigations and overall programme direction. He has chaired the International Technical Advisory Committee and the International Board of Counsellors of the Nuclear Waste Management Organization of Japan (NUMO) (the high-level waste organization of Japan) and also the Nuclear Advisory Committee of the Swiss Paul Scherrer Institute. For eight years he served on the US National Research Council's Board on Radioactive Waste Management, latterly as Vice-Chairman.

He received a B.Sc. degree in physics from the University of Aberdeen, Scotland, and a Ph.D. degree in physics from the University of Bristol, England.

Alan Brownstein – Consultant

He completed his nearly 40 year career in federal service retiring in 2017 as the Associate Deputy Assistant Secretary in the US Department of Energy's Office of Nuclear Energy. During his ten years with the Office of Nuclear Energy,

Mr Brownstein was instrumental in supporting and guiding the International Framework for Nuclear Energy Cooperation's Reliable Nuclear Fuel Services Working Group including serving as the Co-Chair.

Mr Brownstein also served 25 years with the Yucca Mountain Project in many leadership positions including serving as the Chief Operating Officer. Mr Brownstein began his career on the research faculty of the Pennsylvania State University supporting the Governor's energy office and worked for General Public Utilities before, during, and after the accident at Three Mile Island.

Mr Brownstein currently serves as a consultant to the Department of Energy's Office of Nuclear Energy.

Neil Chapman – Vice President of Arius Association

Professor Neil Chapman is among the leading experts worldwide in the geological disposal of radioactive wastes, with four decades experience in environmental, strategic and waste management aspects of the international nuclear industry. He acts as principal adviser and consultant to government organisations and international agencies worldwide on regulatory and safety issues and on structuring scientific research and strategic development programmes.

Key scientific achievements include the first UK experimental studies of the effects of high pressures and temperatures on radioactive wastes, pioneering internationally the use of natural geochemical analogues of materials and processes in deep geological repositories, integration of complex geological data into forecasts of far future evolution of deep systems and, most recently, leading high-profile evaluations of the impacts of natural geological hazards on nuclear facilities. Professor Chapman has a broad working experience encompassing business, academia and government agencies, and has managed both applied research and consulting groups. He has a keen interest in training and education, as well as acting as chairman of many project teams and advisory groups internationally. He is the author/co-author of 9 books and over 200 scientific papers, mainly on geological disposal of radioactive wastes. He is holder of the James Watt Medal of the UK Institution of Civil Engineers.

Stefan Mayer – Team Leader Disposal, Nuclear Energy, IAEA

Dr Mayer is the team leader for radioactive waste disposal (2012-present) in the Waste Technology Section of the Nuclear Energy Department of the International Atomic Energy Agency (IAEA). His work is focused on supporting member states' implementation of disposal solutions providing for permanent, safe containment and isolation of radioactive waste. Information, cooperation and other support requested by member states are delivered through the development of IAEA reports and eLearning modules, the deployment of disposal network activities, the organization of workshops and training courses, expert missions, scientific visits and fellowships. Some of the recent projects aim at developing Agency documents

on a Roadmap for a generic deep geological disposal programme; the management of site investigations; disposal concepts and the design process as implemented around the world; communication and stakeholder involvement in radioactive waste disposal; cost estimation method and funding approaches for disposal programmes; and disposal concepts for small inventories.

Coming from a research and engineering background, prior experience in the waste disposal field was gained during ten years spent working for Andra (2002-2012), the French radioactive waste management organization, in various responsibilities for geological disposal developments.

A first experience was gained during two years spent as a research engineer at the Center for Nuclear Waste Regulatory Analysis (2000-2002), an organization providing technical and scientific support to the US NRC.

Anne Väätäinen – Counsellor of Innovations and Enterprise Financing, Ministry of Economic Affairs and Employment, Finland

Counsellor in the Ministry of Economic Affairs and Employment. Experience: more than 20 years in administration and research in the energy, nuclear energy and nuclear waste management sectors. That includes two years in Vienna (IAEA-related work in the Embassy of Finland), and four years in Paris in Permanent Delegation of Finland to the OECD (IEA- and NEA-related work). Responsible for the administrative preparation and presentation of the decision-in-principle on the final disposal facility of spent nuclear fuel to the government and the Parliament of Finland.

Mika Pohjonen – Managing Director, Posiva Solutions Oy, Finland

Mr Pohjonen has over 25 years of international experience in the energy sector. He has previously held various sales and management positions in the engineering and management consulting business, e.g. in Fortum Oyj and Pöyry. Moreover, Mr Pohjonen has broad expertise in the nuclear energy business acquired in numerous projects in Finland and in most European countries that utilize nuclear energy, as well as in the Middle East and the People's Republic of China. He has also worked as an invited expert in the International Atomic Energy Agency (IAEA) on several occasions.

Anzhelika Khaperskaya – Leading manager, SNF management Project Office, State Corporation ROSATOM

She has been working in the nuclear industry for about 30 years, all her professional activities are related to the nuclear fuel cycle advance technologies development and implementation (SNF management and recycling of nuclear materials).

She has a PhD in physical chemistry. Under her leadership a number of NFC innovative infrastructure projects have been successfully implemented.

She is widely involved in international activity in sharing experience in the nuclear fuel cycle technologies development: in IAEA (TWG NFCO, SNF network etc.), Joint Convention (a vice-chair of the country group for the six review meetings), in NEA (WG on the strategy on the NFC, on the separation chemistry etc.), Nuclear Innovation 2050 forum (a member of the advisory board).

Katsumoto Yoshimura – Director of Technology Office for Radioactive Waste Management, Ministry of Economy, Trade and Industry, Japan

Katsumoto Yoshimura is the Director, Technology Office for Radioactive Waste Management and Director, Public Relations Office for Radioactive Waste Management Development.

He manages the national projects of technical development, also engages to fulfil resources for R&D such as human resource development. And he promotes dialogue activities that deepen the understanding of geological disposal in Japan.

Dave McCauley – Director of the Uranium and Radioactive Waste Division, Energy Sector, Natural Resources, Canada

His responsibilities include the development and implementation of federal policies in the areas of uranium, radioactive wastes, and nuclear liability. With over 20 years of experience on nuclear policy issues, he represents Canada on a number of international committees of the International Atomic Energy Agency and the OECD Nuclear Energy Agency. He holds a Master's degree in Environmental Studies from York University in Toronto, Ontario, Canada.

Robert Mussler – Consultant, International Framework for Nuclear Energy Cooperation (IFNEC)

Robert Mussler currently supports the Nuclear Energy Agency in its work as the Technical Secretariat for the International Framework for Nuclear Energy Cooperation (IFNEC). His experience includes serving as legal counsel in the US Department of Energy, Office of General Counsel, for the US geological disposal programme. After that programme closed he worked for Booz Allen Hamilton on international nuclear policy issues that included financing of nuclear projects, emerging technologies, and the back end of the fuel cycle. He began supporting the activities of IFNEC in 2012 and continues that work as a consultant to the IFNEC Secretariat.

George Borovas – Global Head of Shearman & Sterling's Nuclear Group

Mr Borovas advises governments, lenders and sponsors on the development of nuclear power programmes and the financing and construction of nuclear projects. He has worked on projects and transactions in the United Kingdom, the United States, Russia, Europe, the Middle East, North Africa, Japan, Korea, Southeast Asia, the People's Republic of China, Australia and South Africa. Mr Borovas is a Board Member of the World Nuclear Association (WNA) and is recognised as a nuclear industry expert by the International Atomic Energy Agency (IAEA), and the International Framework for Nuclear Energy Cooperation (IFNEC). Before becoming a nuclear energy lawyer, Mr Borovas worked as an engineer for a nuclear power plant engineering firm.

Robert Sloan – Senior Research Fellow, Energy Faculty, Tulane Law School

Former executive vice president and general counsel at Entergy Corp., has broad-ranging experience in the energy industry in the United States and across the globe. He is currently senior research fellow at Tulane Law School's Energy Center and he has been a senior fellow at the University of Chicago's Energy Policy Institute at Chicago.

Before joining Entergy, Sloan was the managing partner of the Brussels office of a large American law firm and then vice president and general counsel for the worldwide General Electric Industrial Systems subsidiary. He has also worked on nuclear energy issues, at Entergy (the second-largest nuclear power generator in the United States) and on non-proliferation law and policy question earlier in his career in the Office of the Legal Adviser at the US State Department.

Sloan also has handled international corporate, financial, and project-finance transactions in the United States, Western Europe and Asia, as well as complex contract negotiations in French-speaking developing countries. In addition to energy law, he has taught courses on both European Union law and law, literature and the legal profession.

Elise N. Zoli – Partner, Jones Day

Elise Zoli provides strategic direction and advice to the nation's leading public and private enterprises. Her experience focuses on the development, financing (impact investment, hedge fund, private equity, governmental grant, and alternative funding), and operation of clean energy, water, and related infrastructure projects and services. In conjunction with her transactional work, Elise also has pioneered the use of risk-mitigation instruments, including insurance, designed to facilitate new market entrants.

Elise has extensive first-chair experience in large-scale energy- and water-related arbitration and litigation, including on behalf of renewables component manufacturers, energy purchasers, and energy facility owners and operators. Elise has experience that extends beyond transactional work to the use and release of

radioisotopes, as well as the operation, decommissioning, and redevelopment of nuclear power plants, former defence sites, laboratories, and industrial facilities that employ radioisotopes.

Elise is a periodic lecturer at MIT's Sloan School and a member of the clean energy committee for the New England Clean Energy Council.

Elina Teplinsky – Partner, Nuclear Energy, Pillsbury Winthrop Shaw Pittman LLP

She advises clients worldwide on a variety of complex transactional and regulatory issues, including advising on multi-billion dollar nuclear project contracts, structuring nuclear new build projects for bankability, understanding and mitigating nuclear liability risks, developing and implementing nuclear legal and regulatory infrastructure, negotiation and implementation of bilateral nuclear co-operation agreements, and drafting, negotiation and implementation of intergovernmental and host government agreements for the development, construction and operation of nuclear facilities.

Ms Teplinsky was part of the core Pillsbury team advising Brookfield Asset Management on the $4.6B acquisition of Westinghouse Electric Company LLC. She has lead since 2013 Pillsbury's 360 degree advice to Akkuyu Nukleer, the company developing the first nuclear power project in Turkey and is also advising a state-owned enterprise with respect to another new nuclear project in Turkey. She was heavily involved in the firm's advice to K.A.CARE in the development of a peaceful nuclear programme in Saudi Arabia and to United Arab Emirates Nuclear Energy Corporation with respect to the Barakah NPP project. She is also the relationship partner for the firm's assistance to a vendor with respect to that company's nuclear projects in South America, Africa and Asia.

Paul Murphy – Managing Director, Management Department, Murphy Energy & Infrastructure Consulting, LLC

Paul is recognised as an expert in the development and financing of nuclear power programmes by the International Atomic Energy Agency (IAEA), the OECD Nuclear Energy Agency (NEA), the International Framework for Nuclear Energy Cooperation (IFNEC), and the US government.

Edward Kee – CEO & Principal Consultant, Nuclear Economics Consulting Group (NECG)

Mr Kee is an expert on nuclear power economics providing strategic and economic advice to companies and governments on nuclear industry issues.

Xavier Rollat – Alet Business Services Limited

Xavier Rollat is a seasoned senior financier with a comprehensive experience developed during his 29-year career in emerged and emerging countries, primarily in banking and financial advisory services. Xavier has built a solid track record in originating, structuring and arranging single- and multi-source long-term funding solutions to finance capital-intensive investments in the power industry, with a focus on the nuclear power sector.

Timothy A. (Tim) Frazier – Nuclear Economics Consulting Group Affiliate

Tim Frazier is a recognized international expert on the back end of the nuclear fuel cycle and has spoken internationally on the subject. He managed the President's Blue Ribbon Commission on America's Nuclear Future for the Department of Energy.

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