Exploring a Dual Track Spent Nuclear Fuel and Radioactive Waste Disposal Policy for the Hashemite Kingdom of Jordan

Volume Two

Appendices

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Contents

Appendix 1 Current Situation of Radioactive Waste Management in Jordan

Appendix 1 provides further details on the current Jordanian policy, strategy, organizational arrangements and activities related to radioactive waste management. In order to present the reader with a stand-alone text on the Jordanian RWM system, this document may include information from Volume One (Main Report).

A1.1 Jordan's Waste Management Principles and National Policy

A1.1.1 International Requirements on Jordan's RWM Policy, Strategy and Program

Currently, international and most of the national regulatory and legal frameworks in countries generating radioactive waste and spent fuel require the country to establish and maintain a national *policy, strategy, and program* for managing radioactive waste and spent fuel. At the international level, requirements on countries generating radioactive wastes are set in the Joint Convention of the IAEA[1] which has been signed and ratified by 80 countries, including Jordan. A key statement laid out in Article 1 of the Convention is that the Objective is *"to achieve and maintain a high level of safety worldwide in spent fuel and radioactive waste management, through the enhancement of national measures and international co-operation, including where appropriate, safety-related technical co-operation".* In the context of the present study, the explicit mention of international cooperation is important. The requirements make clear that each country must ensure that a credible path to safe disposal of its radioactive wastes is established – but that cooperation, including sharing of facilities can be a component of this path.

It is required by the Convention[1] that Member States should have policies related to the management of spent nuclear fuel and radioactive waste. Article 32 in the Convention requires Contracting Parties to address the following topics in their national reports to the review meetings of the Convention[2]:

(i) spent fuel management policy

(ii) spent fuel management practices

(iii) radioactive waste management policy

(iv) radioactive waste management practices

(v) criteria used to define and categorize radioactive waste.

This requires the Government of Jordan to develop and upgrade its national legislation, technical capabilities, and institutional structures and to construct the necessary facilities for the implementation of the Joint Convention and the national policy for the safe management of spent nuclear fuel and radioactive waste. The national policy will be used as a basis for the preparation and review of national legislations (laws, regulations, instructions) to be in line

[1] Joint Convention IAEA

[2] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, INFCIRC/546, IAEA, Vienna (1997), www-ns.iaea.org/conventions/waste-jointconvention.asp

with these international commitments on environmental protection, safe and secure use of nuclear energy, management of radioactive waste and spent nuclear fuel, radiation protection and nuclear safety and security and others.

The national policy and strategy for managing spent fuel and radioactive waste set out the country's agreed position and plans for managing spent fuel and radioactive waste and are visible evidence of the concern of the government that spent fuel and radioactive waste are properly taken care of.

The national *policy* has a set of established goals and requirements for the safe management of spent fuel and radioactive waste and it also defines related national roles and responsibilities. The national *strategy* presents the actions needed towards Jordan's radioactive waste policy implementation. It also presents technical management options along with the needed national infrastructure for present and future RWM activities. The main function of a *national program* is to set out how the national policy is transposed into practical solutions and it should follow a graded approach when defining, developing and implementing solutions, reflecting the amounts and types of spent fuel and radioactive waste in a State, and the associated risk.

A1.1.2 Jordanian National Radioactive Spent Nuclear Fuel Waste Management Principles

The Hashemite Kingdom of Jordan spent nuclear fuel and radioactive waste management policy aims to manage spent nuclear fuel and radioactive waste in accordance with following national and international accepted practice principles:

- Polluter (generator of waste) pays principle
- Protection of present and future generations
- Transparency and openness regarding radioactive waste management aspects. All RWM activities shall be conducted in an open and transparent manner and the public shall have access to information regarding RWM
- International and Regional cooperation
- Public participation in decision making
- Capacity building and education
- National coordination and cooperative governance
- Sound decision-making based on scientific information, risk analysis and optimization of resources
- Nuclear safeguards requirements shall be considered in the design and the operation of waste management facilities to which nuclear safeguards apply
- Emergency preparedness and response: Arrangements must be made for emergency preparedness and response in case of nuclear or radiation incidents
- Prevention of accidents: All practical efforts must be made to prevent nuclear or radiation accidents
- Provisions of the security of facilities in order to prevent the unauthorized access of individuals and the unauthorized removal of radioactive material
- Sustainable development in view of the long time periods over which radioactive waste and spent nuclear fuel have to be safely managed.

As a Member State of the IAEA, the Hashemite Kingdom of Jordan follows the IAEA Fundamental Safety Principles and abides by international agreements and conventions to which Jordan is a signatory for all the topics related to the safe management of spent nuclear fuel and radioactive waste.

A1.1.3 Scope of the Jordanian SNF and RW Management National Policy

The national policy of the Hashemite Kingdom of Jordan will be applied to the spent nuclear fuel and radioactive waste generated, now and in the future, as a result of the following radiological or nuclear activities:

- Operation of nuclear research reactors
- Operation of nuclear power plants
- Operation of other facilities and processes within the nuclear fuel cycle (including storage and disposal facilities)
- Operation of radioisotopes production facilities at the nuclear research reactors
- The production and use of radioactive material in the field of medicine, industry, agriculture, research, training and education, commerce and defense
- The extraction and processing of raw materials containing Naturally Occurring Radioactive Material (NORM) including (milling and mining of ores containing uranium and thorium, and their radioactive decay products), oil and gas industries and any other activities that containing NORM
- Radioactive waste resulted from radiological or nuclear accidents and emergencies
- Environmental restoration programs associated with any of the above activities (including the decommissioning (D&D) phases of the abovementioned activities).

A1.1.4 Key points in Jordanian National Policy

The National Policy for Radioactive Waste & Spent Nuclear Fuel management, revision 1, which was issued in 2015, is the latest version. This policy demonstrates the national commitment to address the management of spent nuclear fuel (SNF) and radioactive waste (RW) in a coordinated and cooperative manner with all related national organizations and entities. The purpose of this national policy is to ensure that spent nuclear fuel and radioactive waste generated from the nuclear fuel cycle are managed in a safe manner with a full commitment to exclude any hazards or damage to the people and environment both in the short- and the long term. The policy covers all specific steps and stages related to the safe management of spent nuclear fuel and radioactive waste, from its generation through to its final disposal. It documents the nuclear safety and security provisions that aim to protect human health and the environment against radiological and nuclear contamination, currently and in the future, and without imposing undue burden on future generations.

An important aim of the policy is to support the Jordan nuclear energy program, thereby converting the country from energy importer to exporter, while maximizing the exploitation of local resources available for energy. The latest national energy strategy, published in 2020, foresees deployment of a commercial NPP project in a 2030sand nuclear energy is not included in the energy mix in the period 2020-2030.Nevertheless, the management of spent nuclear fuel and radioactive waste is recognized as a national responsibility which must be prepared for and this task was assigned to the JAEC through the Nuclear Energy Law No.42 and its amendments for the year 2007.

The objectives of the national policy for radioactive waste and spent nuclear fuel management are to:

- Set up the generic legal framework, arrangements, measures, actions and all necessary requirements needed to achieve the goals of the safe management of spent nuclear fuel and radioactive waste
- Harmonize and develop the technical, legislative and control concepts associated with the safe management of spent nuclear fuel and radioactive waste
- Protect human health and safety, the environment, and to minimize and reduce the anticipated radiation hazards resulted from the management and disposal of radioactive waste and spent nuclear fuel
- Ensure that the peaceful nuclear applications fulfill all the requirements of nuclear safety and security and the principles of radiation protection which aim to protect the environment and human properties against the hazards and harmful effects of nuclear materials and ionizing radiation
- Dispose of radioactive waste in safe manner at present and at future without imposing undue burdens on future generations
- Minimize the generation of radioactive waste as possible
- Enhance and develop knowledge and technical aspects of the local staff according to international principles and conventions, in order to follow developments in peaceful nuclear applications, particularly for those related to nuclear research reactors and nuclear power plants
- Prohibit any person from importing any radioactive waste from abroad to the Kingdom of Jordan
- Limit and restrict any dealing with and management of spent nuclear fuel and radioactive waste to only the governmental sectors
- Co-operate with the private sector generating the radioactive waste in such a way to cover all the financial costs for the management of radioactive waste and spent nuclear fuel produced at their premises.

The national policy for radioactive waste and spent fuel management currently includes the following main elements:

- Because of the potential to extract remaining fissile material, spent nuclear fuel may be considered as a strategic resource and not as radioactive waste
- Reprocessing within and outside Hashemite Kingdom of Jordan is allowed
- Import of radioactive waste is not permitted
- The establishment of facilities to dispose of radioactive waste is allowed
- Research and development on back-end fuel cycle capabilities is encouraged, based on commercial viabilities, with indigenous capabilities covering radioactive waste management and treatment facilities, spent fuel management and reprocessing facilities, and disposal facilities for radioactive wastes up to and including high (or heat generating) radioactive waste.

A1.2 Organizational Framework

The **Jordan Atomic Energy Commission (JAEC)** was established in 2007 according to Nuclear Energy Law No. 42. and subsequent amendment, empowering JAEC to lead the development and implementation of nuclear energy strategy and to manage the nuclear energy program. JAEC is an independent governmental body, reporting directly to the prime minister, and mandated to articulate a vision, strategy and roadmap to develop the use of nuclear energy for research, nuclear applications in medicine and industry, generating electricity and water desalination. JAEC acts as the effective NEPIO (Nuclear Energy Program Implementing Organization) for Jordan and is supervised by a Council of Commissioners.

The legally, financially and administratively independent entity, **Jordan Nuclear Regulatory Commission (JNRC)**, established in 2007, was directly linked to the Prime Minister. Its mission was to regulate and control the use of nuclear energy and ionizing radiation, protect the environment, human health, and property from hazards of contamination and exposure to ionizing radiation, and to ensure the fulfilment of requirements of public safety, radiation protection and nuclear safety and security. In 2014, the **Energy and Minerals Regulatory Commission (EMRC)** was established, merging the JNRC with the Electricity Sector Regulatory Authority, which includes within its organizational structure the Commission responsible for regulation of the peaceful uses of nuclear energy.

A1.3 Allocation of Responsibilities

The responsibilities for the management of spent nuclear fuel and radioactive waste in The Hashemite Kingdom of Jordan are distributed over the following main parties:

- **Government:** The Government must ensure and maintain the availability of the resources (human, financial, technical) in Jordan to facilitate the implementation of the national policy and the associated national strategy related to the management of spent nuclear fuel and radioactive waste[3]. As mandated by laws 42 and 43, it has tasked JAEC and EMRC with the following responsibilities which are listed in more detail in further subsections
    - **JAEC:** is responsible for the administrative and generic management activities related to the control, coordination, preparations and implementation of plans, efforts and approaches by which the process of managing SNF and RW, including disposal, would be practically and effectively completed.
    - **EMRC:** ensures the implementation of the National Policy and its inclusion in national legislation issued in cooperation with other regulatory bodies such as the Ministries of Environment and Health, and other relevant national entities. The EMRC regulates and controls use of nuclear energy and enforces implementation of national regulations on SNF and RW management. It grants licenses, ensures fulfilment of requirements for public safety, radiation protection of workers, and nuclear safety and security.
- **Generators and Operators**: Generators of spent nuclear fuel and radioactive waste or operators or managers of radioactive waste storage and treatment facilities are responsible for: all the technical, financial and administrative short-term management

[3] In October 2020, the Nuclear Fuel Cycle Commission at JAEC completed the final draft for the National Strategy for Radioactive Waste and Spent Nuclear Fuel Management after being reviewed and discussed by both EU and IAEA experts. Currently, JAEC staff are working with the international experts to develop the strategy action plan to be finally presented to the Board of Commissioners at JAEC for final official approval and endorsement.

of their waste within their facilities. These generators and operators are also responsible for the development and updating of SNF and RW management plans within their facilities based on the national strategy in Jordan for managing SNF and RW. Other responsibilities, such as minimizing generation of RW and keeping records on the SNF and RW inventory, which should also be fulfilled by these generating facilities are included in the listing below.

A1.3.1 Responsibilities and Activities of JAEC

- The long-term management of spent nuclear fuel and radioactive waste
- Radioactive waste management of orphan sources
- Ensuring a national coordinated approach to long term management of spent nuclear fuel and radioactive waste, and to manage the radioactive waste for which no other organization has responsibility
- Fulfilling national and international obligations in terms of international agreements and conventions associated with the long-term management of spent nuclear fuel and radioactive waste, and radioactive waste for which no other organization has responsibility
- Preparing and updating the national strategy for spent nuclear fuel and radioactive waste management emerged from the policy
- Ensuring adequate competence and capacity within JAEC in the field of radioactive waste and spent nuclear fuel management
- Ensuring that radiation exposures resulted from the radioactive waste and spent nuclear fuel management will be kept as low as reasonably achievable (ALARA), while taking into account economic and social factors
- Implementing practical and feasible management of spent nuclear fuel and radioactive waste
- Disposal of spent nuclear fuel and radioactive waste
- Provision of institutional control over the closure of disposal facilities for the radioactive waste and spent nuclear fuel storage and processing facilities during operations and decommissioning stages
- Establishing and implementing a quality assurance program for all the stages of management of spent nuclear fuel and radioactive waste
- Establishing and operating national facilities for the long-term management of spent nuclear fuel and radioactive waste
- Ensuring maintenance of records and a system of reporting for radioactive waste and spent nuclear fuel
- Setting up the waste acceptance criteria for the national facilities designated for storage, management of radioactive waste and future disposal
- Ensuring that the packaging and packages of conditioned radioactive waste conform to the requirements established by EMRC
- Preparing reports on the assessment of risks and environment impact for the national facilities designated for storage, management of radioactive waste and future disposal
- Proposing adequate technical options and approaches for the predisposal and disposal of the radioactive waste and spent nuclear fuel management in the country.

JAEC undertakes in a cooperative manner with all relevant national authorities, the formulation of the national strategy for spent nuclear fuel and radioactive waste management for the implementation of this national policy and JAEC will establish a national committee for this purpose.

To fulfill its responsibilities, JAEC carries out a wide range of activities related to the management of RW and SNF generated at the territory of Jordan. JAEC ensures the availability of adequate information (radioactive waste inventories, etc.) and resources. All RWM's steps (processes) such as collection, pretreatment, characterization, classification, treatment, conditioning, handling, transportation, storage and disposal, are being or shall be established under the authority of JAEC as an acting National RW Management Organization.

There are three main sites hosting RW processing and storage facilities: The Centralized Storage Facility (CSF) at JAEC headquarters site, the Radioactive-Waste Treatment Facility (RTF) at Jordan Research and Training Reactor (JRTR) site and the historical RW storage pit at the Sewaqa waste management site. JAEC is the operator of the CSF and the RTF and retains responsibility for RW stored at Sewaqa site while the site is formally under the management of the Ministry of Environment. Those facilities are distributed over the territory of Jordan and are at different phases of their life cycle, have significantly different design features, achieved level of safety and security, as well as differ in resourcing for RWM activities.

JAEC operates the JRTR research reactor, but its primary responsibilities are the development and eventual deployment of commercially viable nuclear power plants for energy generation in Jordan. This deployment comes as part of Jordan's efforts for energy diversification and the implementation of Jordan's national energy strategy in which nuclear power generation can be an integral component. Accordingly, JAEC has embarked on an ambitious project to deploy a large NPP with around 1000 MWe and signed a Project Development Agreement (PDA) with Rosatom Overseas for that purpose in 2014, following an extensive period of technology selection and evaluation. For various reasons, including deteriorating market conditions (low growth in electricity due to the regional economic situation), the PDA was subsequently terminated.

JAEC thereafter commenced evaluation of small modular reactors (SMRs) as a viable alternative for medium term deployment, recognizing the potential advantages that these possess (suitability for small grid, smaller upfront investment, flexibility in deployment, etc.). Currently, JAEC is concentrating on the technical and economic evaluation of viable SMR technologies that could meet Jordan's requirements and to be deployed in 2030s timeframe.

A1.3.2 Responsibilities of EMRC

- Ensure the implementation of the national policy for radioactive waste and spent nuclear fuel management and include its contents in the national legislations issued by EMRC in a cooperative manner with other national regulatory bodies such as the Ministry of Environment (MoE), Ministry of Health (MoH), and other relevant national entities
- Regulate and control the use of nuclear energy and ionizing radiation and the management of radioactive waste and spent nuclear fuel
- Maintain a national registry for all radiation sources and radioactive materials that are in use or imported or exported or disused sealed radiation sources including orphan sources in any form (sealed or not sealed sources)
- Enforce the implementation of the national regulations on radioactive waste management and spent nuclear fuel in a cooperative manner with other national governmental organizations

- Ensure the fulfillment of requirements of public safety and radiation protection for workers, and nuclear safety and security for radiological and nuclear activities and facilities including practices for radioactive waste and spent nuclear fuel management
- Grant licenses and permits for radiation institutions, nuclear facilities, and workers in the radiation and nuclear fields including practices for radioactive waste and spent nuclear fuel management
- Issue national regulations related to the following:
    a. Safe use of nuclear energy.
    b. Safety and security of radiation sources.
    c. Radiation protection.
    d. Management of radioactive waste and spent nuclear fuel.
    e. Transport of radioactive materials.
    f. Extracting, mining and processing of the nuclear materials.

A1.3.3 Responsibilities of Generators and Operators

Generators of spent nuclear fuel and radioactive waste or operators or managers of radioactive waste storage and treatment facilities shall be responsible for:

- The technical, financial, and administrative short-term management of their waste within their facilities according to the national legislations
- The financial long-term management of their radioactive waste and spent nuclear fuel which will be technically and administratively managed by JAEC
- Developing, updating and implementing the spent nuclear fuel and radioactive waste management plans within their facility based on the national spent nuclear fuel and radioactive waste management strategy which is adopted by EMRC
- Establishing appropriate radioactive waste and spent nuclear fuel management facilities
- Minimizing the generation of radioactive waste as far as can be practicably achieved
- Keeping records on the spent nuclear fuel and radioactive waste inventory
- Establishing and implementing a quality assurance program for radioactive waste and spent nuclear fuel management
- Ensuring that the generated radioactive waste is within the waste acceptance criteria established by JAEC.

An additional responsibility as defined in the Instructions on Radioactive Waste Management and Instructions on the Spent Fuel Management issued by the EMRC in 2015 is that generators must prepare and submit initial decommissioning plans or waste processing and storage facilities since this is considered as part of the required documentation for operation license application.

A1.4 Management of Spent Nuclear Fuel

The National Policy for Radioactive Waste and Spent Nuclear Fuel Management states the main requirements for appropriately managing these materials in a safe and secure manner and states that the government can take relevant decisions to ensure that this is achieved:

- Spent nuclear fuel should be stored on an interim basis in pool storage at the nuclear research reactor or nuclear power plant site until it has decayed to sufficient levels to allow for safe dry storage
- Storage facilities should be established near the nuclear research reactor or nuclear power plant for further cooling
- Spent nuclear fuel can be returned to the country of its origin (i.e., the supplier) for final disposal or interim storage or kept in Jordan in an interim storage for either of the two following options:
    - Treating the spent nuclear fuel as a strategic resource that can be utilized through reprocessing (nationally or internationally), with disposal of the resulting HLW in a national waste disposal facility in Jordan
    - Treating the spent nuclear fuel as radioactive waste, thereby allowing it to be disposed of directly in a national waste disposal facility.
- National facilities should be established for disposal of low and intermediate level waste (LILW) in Jordan.

A1.4.1 Strategy Options for Managing Jordanian Spent Fuel

The current national strategy states that, after storage at the reactor, different technical options will be considered, as follows:

1. Return of the spent fuel to the country of origin (the take-back approach). This option is called “Return to its origin (Manufacturer)”, which allows the fuel supplier to choose its own end point – direct disposal or reprocessing with no return of HLW to Jordan.
2. Shipment of the spent fuel outside Jordan for reprocessing, with the HLW generated from reprocessing shipped back to Jordan for final disposal in a national deep disposal facility. This option is called “HLW disposal in Jordan after SNF reprocessing outside Jordan”.
3. Storage of spent fuel in Jordan to allow for its direct disposal at the national deep geological disposal facility to be implemented in Jordan. This option is called “Direct disposal in Jordan”.

A fourth option, to dispose of spent fuel and/or the HLW generated by reprocessing in a multinational facility in a third-party country, is not currently part of the strategy, but is central to the topic of the current report. This fourth option would be required for Jordan to fully adopt the dual track approach. This option would then be pursued in parallel to the national approach included in options 2 and 3, which both require JAEC to construct and commission a Deep Geological Disposal facility and a conditioning facility with associated infrastructure [4]. All technical options include safe storage at the site of nuclear installation and the following steps in management of SNF up to the final disposal are described as shown in Figure A1-1.

Based on the Action Plan for implementation of the National Strategy for the Safe Management of RW and SNF prepared by JAEC, it is anticipated that the implementation of the Strategy will commence in 2021 with expected implementation period up to 2045. However, the timescales of this Action Plan could be revised and updated based on future developments. The Strategy is proposed to be implemented as follows:

- Phase I: Improvement of the national RWM framework (duration: 4 years)

[4] JAEC, *The Hashemite Kingdom of Jordan National Policy for Radioactive Waste & Spent Nuclear Fuel Management*.

- Phase II: Improvement of technical capacities, investigation of options and preparation of the decision for disposal of all RW (duration: 10 years)
- Phase III: Creation of routes for disposal of current and committed future RW, disposal of all classes of RW (requiring disposal) and continued predisposal management and disposal of newly generated RW avoiding the creation of burdens (duration: 10 years).

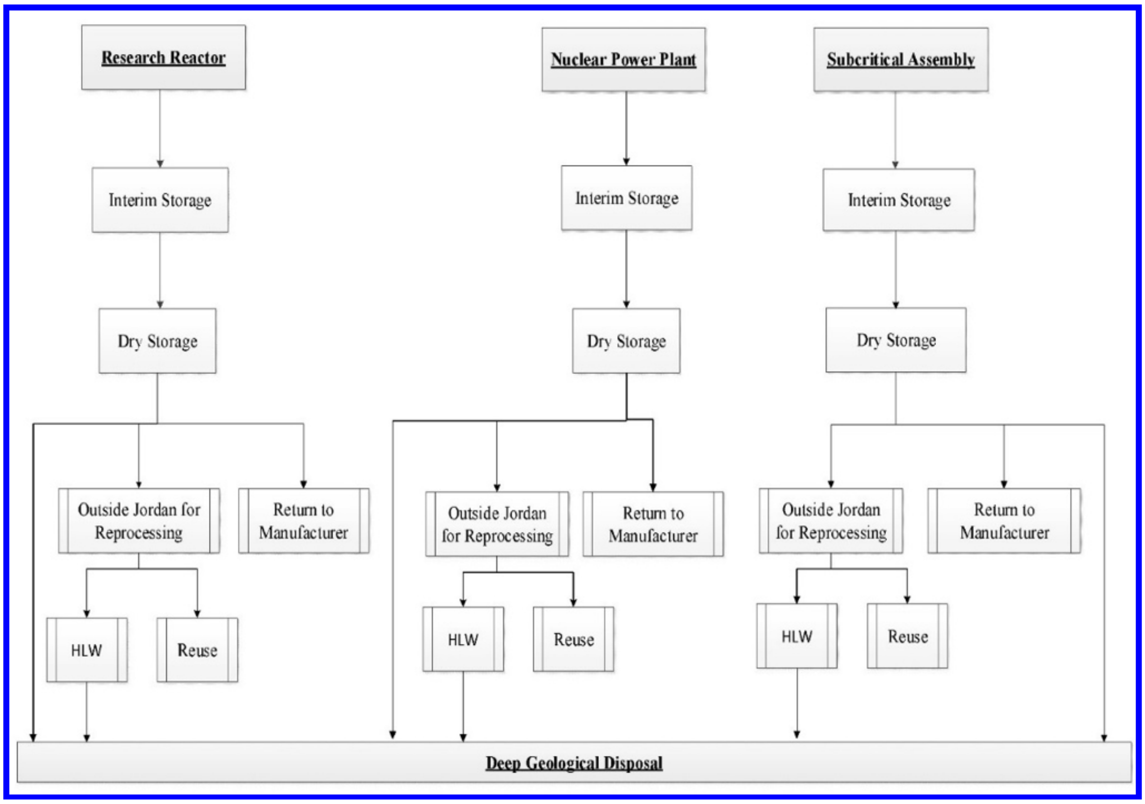

Figure A1-1: Technical Options for the Management of Spent Nuclear Fuel

A1.4.2 Current Jordanian Restrictions on the Export/Import and Transfer of Ownership of SNF and RW

Export / Import

Law no. 43 for the year 2007 lays the foundation for limiting the import and export of radioactive materials across Jordanian boarders. Importing or exporting radioactive materials (including radioactive waste) without a license is prohibited by law. Transportation specifications of radioactive materials and its requirements have been specified within Regulations on Radioactive Materials Transportation No. 32 of 2016 [5].

The national policy for radioactive waste and spent nuclear fuel management states[6]:

- It is prohibited for anyone to transport or import any type of radioactive waste material from abroad to the Kingdom of Jordan, with the exception of spent nuclear fuel returned after storage in the country of origin or radioactive wastes derived from the reprocessing abroad of Jordanian spent fuel.

[5] Official Gazette, *Nuclear Materials Transportation Regulation*, 2016.

[6] EMRC, 'Instructions on Decommissioning Nuclear Facilities'.

- It is forbidden to import any material classified as RW to the territory of Jordan, or use, handle, transport, store, dispose of or bury it in the territory of Jordan
- It is prohibited to carry out any activity related to radioactive waste and spent nuclear fuel inside domestic nuclear facilities unless these materials are of Jordanian origin
- Jordan will pursue international and regional solutions for the long-term management of spent nuclear fuel and radioactive waste produced in Jordan.

EMRC will be responsible for preparation of a national registry for all radiation sources and radioactive materials that are in use or exported or imported[7].

Based on Nuclear Security Instructions for Nuclear Installations and Facilities, Nuclear Material and Related Activities, any person wishing to import or export nuclear materials must apply to the authority to obtain a related license[8].

Transfer of ownership of SNF and HLW

Within the radioactive waste management strategy principles, it is stated that the transfer of nuclear radioactive waste between generators can be considered, provided that all issues associated with liability, ownership and safety are addressed. As noted above, the current legislative framework does not currently cover the transfer of ownership of SNF and HLW in an international framework, and this issue must be addressed in any developments towards the adoption of a dual track approach. During the transfer of ownership of SNF and HLW, all safety and security principles must be complied with, according to the regulations published by the Jordanian regulator (EMRC). In all aspects of the process during the transfer of ownership, the government of Jordan oversees and controls how operator/generator performs their tasks and completing the transfer under the specified standards.

A1.5 Potential Future Jordanian Spent Fuel Inventories and Management Options

This section discusses how future nuclear power scenarios can affect the amount of waste generated.

A1.5.1 Spent Fuel Management in Jordan

In Jordan, according to the National strategy, SNF is managed based on its source, whether it was Jordan Research and Training Reactor (JRTR), Jordan Subcritical Assembly (JSA) or Jordan Small Nuclear Power Plant (JSNPP).

JSA

SNF assemblies generated in the JSA are stored in a long-term storage pool. SNF is then managed in parallel with the future SNF from JRTR and the NPP.

JRTR

The JRTR, which is the only research reactor in Jordan, started operation in November 2017. Spent Fuel Assemblies (SFAs) discharged from the reactor core are currently stored at the

[7] JAEC, *The Hashemite Kingdom of Jordan National Policy for Radioactive Waste & Spent Nuclear Fuel Management*.

[8] Official Gazzette, *Radiation Protection and Nuclear Safety and Security Law*, 2007 <http://dx.doi.org/10.1016/j.apmr.2003.08.004>.

service pool, and current plans are to maintain their safe storage in the service pool until the end of the reactor lifetime. The reactor service pool is designed and constructed for safe storage of SNF assemblies and is sized-sufficiently to store all SNF assemblies produced from JRTR operations during its entire lifetime.

The current options are considered for managing SNF generated by the JRTR after storage at the reactor service pool for decay heat removal:

1. **1.** Return the spent fuel to the country of origin for processing and final disposal (take-back approach). This option is called “Return to Manufacturer”.
2. **2.** Ship the spent fuel outside Jordan for reprocessing, with the HLW generated from reprocessing shipped back to Jordan for final disposal in a national deep disposal facility. This option is called “Outside Jordan for Reprocessing” on.
3. **3.** Declare the spent fuel as radioactive waste and implement its direct disposal in a dedicated national deep geological disposal facility in Jordan.

The 2nd and 3rd options require JAEC to construct and commission a long-term SNF storage facility at the reactor site. Both the 2nd and 3rd options also require a national deep geological disposal facility and a facility for conditioning the SNF / HLW and other generated operational RW before disposal.

JSNPP

In this case of SNF generation, it is first on a temporary basis stored in SNF storage pools until the fuel requires no further water cooling. And then it is relocated to dry storage facilities on-site.

The further options described in the national strategy are identical to those listed above for JRTR fuel. Again, in the absence of a “take-back” option involving return to the manufacturer, Jordan will require a national deep geological disposal facility and a facility for conditioning the SNF / HLW.

A wider and more detailed assessment of the global options that might be available is presented in the following section.

A1.5.2 Potential SNF Management Options for Jordan

Every country should develop a national storage and disposal approach nationally, as discussed in IAEA document NW-T-1.24 Rev.1. Any country starting up a nuclear power program needs to have a baseline strategy that involves all waste management operations for all waste types being carried out at a national level, and this requirement must be fulfilled by Jordan. However, this does not exclude parallel development of a dual track approach that is kept open until a final decision is made. Below, all internationally potentially available SNF management options are considered below for both national and dual-track approaches, and assessments are made on their potential for being utilized by Jordan in its nuclear power program. All potential strategies are taken into account, whether they are documented in Jordanian legislation or national policy, or whether they present wider possibilities. The options considered are as follows:

1. Reprocessing of SNF abroad and disposal of the generated waste nationally. This would need to be negotiated with the reprocessing service provider. Currently, Jordan has limited possibilities to go for this option, for several reasons such as the scarcity of technical vendors that offer reprocessing and the fact that the choice of reactor technology has not as yet been decided. The benefits would include early removal of spent fuel from the reactor site, postponement of the building of interim storage facilities, since the HLW will not be returned for several years, lower storage and

disposal volumes for HLW than for spent fuel, and reduced proliferation concerns, since fissile materials need not be returned from the reprocessing service provider. The main disadvantage is the cost; today, recycled fuel is more expensive than fresh fuel; the reprocessing costs arise early; the reduction in disposal costs for HLW relative to spent fuel are uncertain. A further significant drawback is that the ILW, which is also returned to the country, increases the volume for disposal and can present greater long term safety concerns than vitrified HLW, which is a high-quality product that can be packaged in very long-lived containers.

2. Reprocessing and disposal of the wastes outside Jordan. This option is primarily governed by the availability of a reprocessing service provider that is willing to offer disposal services as well. This option has one major advantages in addition to those resulting from the reprocessing itself, namely, the lower probability of facing opposition from the public. However, the cost could be a serious obstacle.
3. Storage of SNF in a national facility and then transfer to a multinational repository (MNR). The economic benefits of an MNR to a small country such as Jordan can be more easily achieved if the shared disposal facility is based on a partnering approach in which all participants expect to benefit from the economies of scale involved. Hence, this approach for smaller nuclear programs has potential benefits over the national approach for managing radioactive waste and spent nuclear fuel.
4. Fuel leasing in which the nuclear fuel used in the Jordanian reactor remains the property of the fuel provider. This is considered an easier approach from political and legal points of view. The international non-proliferation community has strongly favored fuel leasing approaches, since a much tighter control of fissile materials results. However, no offers from fuel providers are currently available.
5. Finally, the option of retaining SNF in storage for long times has many positive features, such as the fact that spent fuel can be relatively easily stored for long periods of time and expensive disposal facility projects are postponed which gives the country enough time to decide and take the necessary preparations to develop cooperation and partnerships with countries in the region and construct a multinational repository. In addition, spent fuel may become an asset if reprocessing costs decline and uranium costs increase. On the other hand, the downsides of this option might be related to the public acceptance and the political perceptions of nuclear power.

Bearing in mind these options, the potential future radioactive waste inventory in Jordan is discussed in the following Section.

A1.5.3 RW Inventory Development, Assumptions and Estimations

The NPP technologies that were assumed for these estimates are mainly generation 3+ or higher, with the exclusion of the reprocessing option. Units for SNF inventories are: tHM (tonnes of heavy metal), number of fuel assemblies and m^3 (cubic meters).

SNF generation in Jordan is not yet in progress, apart from the 222 SNF units that will be in the SNF pool in JRTR by the end of its lifetime.

The proposed future NPP program was assumed to include from 2000 to 4000 MWe power plants (Pressurized Water Reactor (PWR) and High Temperature Gas Cooled Reactor (HTGR) Small Modular Reactor (SMRs) with a Large Nuclear Power Plant (LNPP) having 60 years lifetime, assuming 100% utilization, no unscheduled outages, no failed fuel elements, no accidents and no fuel design changes. For any PWR technology considered in this report, a 24-month refueling cycle was assumed, replacing one third of the core at each outage. These assumptions imply that nuclear energy will represent from 20-40% of the expected installed electrical capacity by 2040.

For the available HTGR designs, the spherical fuel element has a radius of 3 cm and 7g of fuel content. These reactors discharge 720 fuel elements (spheres) annually at 200 MWe and 0.9 capacity factor. For more information, it is worth noting the novelty of HTGR fuel design, the limited operational experience compared to PWRs and the fact that no reprocessing technologies are available as yet. The HTGR's SNF designated for disposal consists mainly of large volumes of graphite. Nevertheless, the handling requirements are less due to its superior retention capabilities.

PWR SMR refueling shutdowns take place every 2 years, with each replacing 13 fuel assemblies. This generates 28 m^3 SNF for a 1000 MWe equivalent to 40 tHM per fuel cycle.

Large NPPs generate approximately 20 tonnes of SNF each year for a 1000 MWe LWR[9], having a volume of approximately 10 m^3.

Jordan is still evaluating the available options in order to decide the appropriate technology mix to be deployed in the country. SNF and HLW generated volumes depend on the reactor technology being utilized. Currently, different reactor technologies are under consideration, including NuScale, RITM-200, SMART, Xe-100 and HTR-PM. For each of the following cases, inputs were adopted from specific design characteristics, based on availability of information. Table A1-1 demonstrates reactor technology deployment and the potential scenarios in Jordan.

Table A1-1: Total amounts of SNF assumed to be generated for four nuclear power scenarios.

<table>
<tr><th>Scenario</th><th>Description</th><th colspan="3">SNF/ year [tHM]</th><th colspan="3">SNF / 60 Years Lifetime [tHM]</th><th>Total Expected SNF [tHM]</th></tr>
<tr><td rowspan="2">S.1</td><td rowspan="2">2000 MWe HTGR
2000 MWe LNPP</td><td colspan="2">HTGR</td><td>LNPP</td><td colspan="2">HTGR</td><td>LNPP</td><td rowspan="2">3036</td></tr>
<tr><td colspan="2">10.6**</td><td>40*</td><td colspan="2">636</td><td>2400</td></tr>
<tr><td rowspan="2">S.2</td><td rowspan="2">2000 MWe PWR SMR
2000 MWe LNPP</td><td colspan="2">PWR SMR</td><td>LNPP</td><td colspan="2">PWR SMR</td><td>LNPP</td><td rowspan="2">4800</td></tr>
<tr><td colspan="2">40</td><td>40</td><td colspan="2">2400</td><td>2400</td></tr>
<tr><td rowspan="2">S.3</td><td rowspan="2">2000 MWe HTGR
2000 MWe PWR SMR</td><td colspan="2">HTGR</td><td>PWR SMR</td><td colspan="2">HTGR</td><td>PWR SMR</td><td rowspan="2">3036</td></tr>
<tr><td colspan="2">10.6</td><td>40</td><td colspan="2">636</td><td>2400</td></tr>
<tr><td rowspan="2">S.4</td><td rowspan="2">1000 MWe HTGR
1000 MWe PWR SMR
2000 MWe LNPP</td><td>HTGR</td><td>PWR SMR</td><td>LNPP</td><td>HTGR</td><td>PWR SMR</td><td>LNPP</td><td rowspan="2">3918</td></tr>
<tr><td>5.3</td><td>20</td><td>40</td><td>318</td><td>1200</td><td>2400</td></tr>
</table>

*1 GWe generated from a PWR produces 20 tHM annually, assuming 90% capacity and 50 GWd/tHM[10].

** Since TRISO fuels are HALEU and have high burnup levels, an assumption was made of 95% TRISO SNF content as heavy metal, based on 7 g initial content in each kernel[11].

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9 (IAEA, Options for Management of SNF and RW for Countries Developing New Nuclear Power Programmes, 2018)

10 International Panel on Fissile Materials (IPFM), Managing Spent Fuel from Nuclear Power Reactors - Experience and Lessons from Around the World, 2011

11 Treatment and recycling of spent nuclear fuel Actinide partitioning – Application to waste management, CEA Saclay and Groupe Moniteur (Éditions du Moniteur), Paris, 2008

Figure A1-2 shows the expected amounts in tHM of expected SNF for the assumed lifetime of nuclear reactors generated using the scenarios explained in Table A1-1.

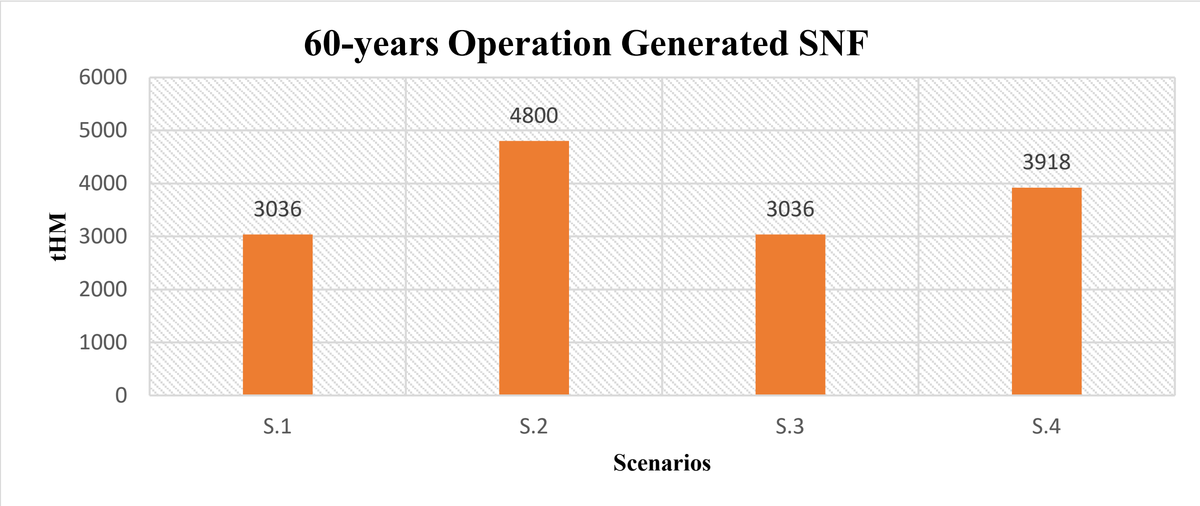

Figure A1-2: Estimated amount of SNF over 60 years operation [tHM].

Analysis of Scenarios within Jordan

The largest amount of SNF generated (in tHM) annually is expected for S.2: 2000 MWe LNPP and 2000 MWe PWR SMR. This is mainly due to the fact, that PWR technologies generate SNF with higher heavy metal content, as well as the components of S.2, being built only on PWR basis. SNF from HTGR power plants under consideration are not expected to exceed 11 tHM annually. The least SNF volume generated is in S.1 and S.3 which include HTGR as well as PWR technology. The requirements for HTGRs SNF handling, storage containers and facilities are much less than those for PWRs. An important factor influencing the costs of SNF management is the intermediate storage until disposal. Storage costs of storing different types of SNF may vary considerably. To weight scenarios against each other, the economic impact of each must be taken into account.

Discussion and Conclusions

Each of the approaches has beneficial characteristics and also drawbacks. In case the option adopted was long-term storage of SNF, this gives the country the freedom to keep open decisions on whether to keep it stored, to dispose of it in an MNR, or the disposal in a national repository. While the SNF is stored, the country avoids the costs of expensive disposal facility project development, and this offers time to decide and take the necessary preparations to develop cooperation and partnerships with countries in the region and construct a multinational repository. It also provides more time in which to accumulate, for example by electricity tariffs, the funds needed for implementing a GDF. However, SNF will in any case be stored for decades to allow cooling before disposal, so that these storage benefits arise for almost all scenarios.

For disposal, the benefits to a country with a small nuclear power program such as Jordan can be more easily achieved if the shared disposal facility is based on MNR solution in which benefits from the economies of scale are guaranteed. Jordan will have the time to initiate and promote the concept supported by the Arab Atomic Energy Agency (AAEA) to develop and finally help realizing the dual-track approach in the region as proposed in section A1.6 below and eventually to participate in a specific MNR project.

Options 2 and 3 in section 1.5.2 involving reprocessing might be utilized in conjunction with the MNR option, making these the second most favorable path in the direction of a multinational solution.

Fuel leasing excludes both national and an MNR disposal approaches, since the SNF will be returned to the supplier with no further responsibilities.

A1.6 Jordan's Position Regarding the Dual Track Approach

Due to a diversity of circumstances in the region, including the political and economic situation, Jordan has faced setbacks in the last decade which affected the progress towards building a nuclear power plant. It is necessary to seek options that might improve and speed up the process of implementing the NPP project, since this will help Jordan realize the nuclear project objectives of achieving energy security and national development.

Although, the national legislative framework does not explicitly discuss regional and international options for SNF and RW long-term management, the national policy expresses Jordan's interest in investigating all options for SNF and RW long-term management. A main purpose of the present study is to evaluate what would be required for Jordan to first implement the dual track approach and thereafter to actively promote, develop and participate in such potential regional and international initiatives. As described above, the only foreign options currently included in the strategy that Jordan is implementing for managing SNF and HLW involve transfers to and from the country supplying the reactor fuel or to another country for reprocessing. However, the policy of Jordan is meant to be reviewed and updated periodically, and for a full dual track approach, updates will have to take into consideration the following options:

1. Returning SNF to supplier, which can then choose its own end point including disposal in its own territory or export to an MNR elsewhere
2. Shipment to any third country that operates an MNR (not the supplier of fuel).

As Jordan has a relatively small nuclear program, the financial and human resource investments required for the construction and operation of a geological disposal facility will be challenging and daunting. As laid out in the main report, multinational repositories can offer economic, technological, human resources, environmental, societal and non-proliferation benefits for both the host and for Jordan. Dual-Track approach can comprehensively provide Jordan with the necessary resources (technical, human, legislative, etc.) to develop its national plans towards the implementation of SNF and RW long-term management, in collaboration with other countries having nuclear power programs in the region. All of the above will in turn improve how Jordan is going to deal with its future generated waste by the Jordanian nuclear program. For Jordan implementing dual track in the initial phase after its adoption, tasks and activities will be complementary to a national repository program and will require the commitment of relatively modest resources as is the case in other countries.

Thus, for Jordan, a prudent strategy may be to adopt a dual track approach in which the options of a purely national approach and multinational sharing are both kept open. However, a definitive choice requires closer consideration of the key issues involved.

A1.7 Arab Region Nuclear Fuel Cycle

At present the only country in the Arab region with an operating nuclear power plant is the UAE. Others with plans to introduce nuclear power are Saudi Arabia and Jordan and in Egypt implementation is underway. Other GCC (Gulf Cooperation Council) countries have expressed interest in nuclear power but none of them is likely to move forward with this in the near future.

The UAE excluded the options of national enrichment and reprocessing plants when it signed the US 123 agreement for nuclear cooperation which allows transfer of nuclear knowledge and capabilities. Accordingly, it will be dependent on a variety of fuel supply contracts to secure fuel procurement and takeback for reprocessing. The UAE's intentions for front-end of the fuel cycle are much clearer than those for the back-end, as described below.

Fuel cycle activities in Saudi Arabia are currently limited to an exploratory study and feasibility assessment of uranium and thorium resources in the Kingdom, conducted by the China National Nuclear Corporation and the Saudi Geological Survey (Reuters, 2017). The project results are due in 2022 and cover exploration in nine areas across the Kingdom, in addition to ongoing feasibility studies regarding fuel supply chain localization. Saudi Arabia has also signed a separate agreement with Jordan for uranium exploration and yellowcake production in central Jordan[12]. Saudi Arabia has not undertaken to forgo uranium enrichment and reprocessing activities.

In 2013, Egypt's Nuclear Materials Authority (NMA) re-stated the government's long-held claims that the country is home to vast uranium ore deposits around the Red Sea and Sinai region[13]. In 2015, the government opened an international bidding process for exploration and mining companies to explore at least three of the most promising uranium deposits. Egypt does not have any conversion or enrichment capabilities, though it once operated a reprocessing and fuel fabrication lab for a Russian research reactor built in 1961. Egypt and Rosatom concluded that a storage facility will be built beside the NPP to hold the SNF from the reactors before it is sent to Russia for reprocessing. Commissioning is anticipated to be in 2026 and the project is expected to be completed in 2028-2029.

Jordan has had extensive activities in uranium exploration and production since 2009 and, in March 2017, JAEC and Saudi Arabia's KA-CARE signed the above-mentioned agreement[14].

Hence, these four countries together have nuclear expertise, uranium ore deposits, research reactors, fuel fabrication skills on a small scale, accelerators, and other nuclear-related laboratories, including hot cell laboratories. These are the capabilities that are necessary to develop an integrated regional nuclear fuel cycle.

The idea of a common Arab Fuel Cycle has received support from many policy makers, expert working groups and formally from the Arab League which has tasked the Arab Atomic Energy Agency (AAEA) to develop the concept - but there has been little progress so far. An Arab fuel cycle could ensure fuel supply for Arab nuclear reactors and share in the technological and economic developments of an integrated fuel cycle activities. Unfortunately, UAE is not a member of the AAEA. Another option to develop further this concept could be via Cooperative Agreement for Arab States in Asia for Research, Development and Training related to Nuclear Science and Technology (ARASIA) but, in this case, Egypt is not a party.

Some of these four countries have communicated their fuel cycle plans, including storage and disposal options. The UAE's short-term plan is to store its irradiated fuel in spent fuel ponds for 20 to 30 years. The UAE has a base scenario for disposal in a deep geological repository in the Emirates, but this could be changed "based on additional opportunities available

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[12] World Nuclear News (March 2017) Jordan and Saudi Arabia team up on uranium, SMRs, Available at: https://www.world-nuclear-news.org/NP-Jordan-and-Saudi-Arabia-team-up-on-uranium-SMRs-2903174.html#:~:text=In%20a%20statement%2C%20Saudi%20Arabia's,of%20uranium%20in%20central%20Jordan.&text=Saudi%20Arabia%20and%20Jordan%20signed%20a%20nuclear%20cooperation%20agreement%20in%20January%202014.

[13] Uranium from phosphates – Current status of Egyptian UxP project. United Nations Economic Commission for Europe. 2015. https://www.unece.org/ fileadmin/DAM/energy/se/pp/unfc/unfc_ws_U.Th_Luxor.Oct.2015/9_ Helmy-Luxor.pdf.

[14] World Nuclear News (March 2017) Jordan and Saudi Arabia team up on uranium, SMRs, Available at: https://www.world-nuclear-news.org/NP-Jordan-and-Saudi-Arabia-team-up-on-uranium-SMRs-2903174.html#:~:text=In%20a%20statement%2C%20Saudi%20Arabia's,of%20uranium%20in%20central%20Jordan.&text=Saudi%20Arabia%20and%20Jordan%20signed%20a%20nuclear%20cooperation%20agreement%20in%20January%202014.

regionally or internationally"[15]. In the past the GCC explored a regional nuclear waste storage and management facility that could serve GCC countries, given the interest in nuclear power in the region.

Additionally, Jordan's JAEC Chairman has stated on multiple occasions that Jordan expects to take part in a regional collaborative project for a common nuclear waste disposal site with the UAE, Saudi Arabia, and Egypt. Jordan has held off on signing the US 123 Agreement to maintain its option of contributing to a regional uranium enrichment facility with Saudi Arabia and Egypt.

However, the formation of an Arab nuclear fuel cycle could most likely proceed only through a series of phases of increasing scope. Success achieved in the first phases may be an incentive to involve other stages and more countries. The regional approach should address the most sensitive parts of the nuclear fuel cycle – namely, uranium enrichment, reprocessing of spent fuel, and spent fuel disposal and storage - and reach acceptable solutions. These are the most important stages in the nuclear fuel cycle from the point of view of non-proliferation and supply, but other stages could be of great interest to a number of countries, such as uranium ore supply, fuel fabrication, and even supply of spare parts to nuclear power plants. Other stages could also be included in a regional arrangement. However, build-up of a regional nuclear fuel cycle in the Arab region could be expected to be slow and gradual.

As soon as possible, the AAEA should be strengthened and restructured to play a pivotal role in the interests of all Arab countries. The experiences of the Tlatelolco Treaty in Latin America and the Caribbean and the Argentine-Brazilian Agency for Accounting and Control of Nuclear Materials (ABAAC) could be instructive.

Establishment of a nuclear-free weapons zone in the Middle East region and abiding by all international treaties, especially the NPT, would be an important perquisite to promote a wider peaceful civilian nuclear energy development in the region and would reduce concerns on nuclear weapons proliferation.

[15] AlKaabi H., UAE Progress on the Development of a national strategy on the management of nuclear waste, Paper 209 IAEA Conference 2019.

Appendix 2 Lessons Learned from Past and Current MNR Activities

Appendix 2 opens with a brief account of the value of international cooperation in the field of radioactive waste management in general. It then presents information on past and current studies on MNR development and draws some conclusions that may be helpful for counties adopting a dual track policy or for proponents of specific MNR initiatives. Examples are then given of how other national RWM programs are implementing or considering a dual track approach. Appendix 2.4 addresses the issue of what impacts the existence of dual track programs might have on advanced national repository programs, and Appendix 2.5 takes a look at which further countries may be in a position to join the numerous programs already following a dual track approach. Finally, some brief remarks are offered on conclusions that can be drawn from experience to date on specific initiatives.

A2.1 Examples of International Co-operation in RWM

There are numerous reasons why collaborative work between two or more countries towards disposal can be advantageous for all participants.

- All costs from R&D work through to major construction can be shared and thus reduced for individual participants
- The pool of expertise is widened, there can be more effective peer reviewing of the results, and world-class knowledge can be tapped
- Suitable facilities for technical work (especially with radioactive substances) may not be available everywhere
- Suitable locations for field work may not be available everywhere for technical or political reasons
- Many of the scientific issues facing waste management experts (especially in the early years) were generic in nature so that solutions have been transferable.

These advantages and benefits have led to a long line of collaborative waste management projects of a bilateral or multilateral type. Some of the best examples cover underground research laboratories (URLs)[16]. There are strong reasons for collaboration: URLs are expensive facilities; various countries (e.g., Spain, United Kingdom) have failed to achieve the public acceptance needed to site URLs; one country might like to study various potential host rocks (granite, salt, clay) without having to construct a test facility in each. Accordingly, many of the URLs of the "first generation" have hosted major international programs. The prime example is Sweden, which has run both the Stripa and later the Äspö crystalline URLs with numerous partners. Similarly, wide participation is a feature of the Grimsel (crystalline) and Mont Terri (clay) laboratories in Switzerland, and several nations have also been active in the Mol facility (clay) in Belgium, the Asse mine (salt) in Germany, and the Canadian URL (crystalline) at Whiteshell. The first operational deep repository at the Waste Isolation Pilot Plant (WIPP) (salt) in the United States is also open for international cooperative experiments.

[16] Brewitz, W., T. Rothfuchs, F. Huertas, and B. Neerdael. 1999 In-situ testing of underground barrier systems in view of PA-relevant parameters. In: Proceedings of Euradwaste 1999, Luxembourg, November 15–18. EUR 19143. Pp. 282–296; McCombie, C., and W. Kickmaier . 1999 Underground research laboratories: Their roles in demonstrating repository concepts and communicating with the public. In: Proceedings of Euradwaste 1999, Luxembourg, November 15–18. EUR 19143. Pp. 274–281.

Joint project work between national programs has not, however, been restricted to URL studies. Engineered barrier investigations (e.g., on spent fuel, high-level waste (HLW) glasses, and bentonite backfills) have also been the subjects of collaborative projects. A further common field for multinational investigations has been natural analogues. One of the most successful examples of cooperation in geological disposal exists between waste management organizations Posiva from Finland and SKB from Sweden. The partnership between SKB and Posiva on research and development was started at the end of the 1970s and intensified in the early years of this century with focus on encapsulation and repository technology and includes now all areas of geological disposal (KBS-3 disposal concept, welding techniques for copper canisters, etc.) as well as agreements on ownership, liabilities, intellectual property, etc. A positive side effect of the SKB-POSIVA collaboration is that it has also led to closer co-operation between the regulators.

Another successful example of cooperation is a European Joint Programme on RW management (EURAD project). EURAD presents a step change in European collaboration towards safe RW management, including disposal, through the development of a robust and sustained science, technology and knowledge management program that supports timely implementation of RW management activities and serves to foster mutual understanding and trust between Joint Programme participants.

Multinational projects of the type described in this appendix commonly are funded and managed by partner organizations from various countries, all with an equal interest in the results and with comparable capabilities for technical and financial contributions. A different type of interaction between national programs has developed in recent years as the experience, skills, and prior investments of some countries have grown significantly beyond those of later entrants to the field. This involves commercially based provision of services. National disposal programs in Sweden, Finland, France and Switzerland all offer support to other countries on a commercial basis.

Whether bilateral or multinational programs are led by governmental organizations or delegated to private enterprise, the prime goal of any nation must be to see that those in charge concentrate on solving the problems of safe and secure management and do not focus instead on prolonging and extending programs or organizations.

A2.2 Past MNR Projects

In seeking a successful path to implementation of any major, long-term infrastructure project, it is prudent to analyze relevant past and present initiatives in order to learn from the experience gained. In the case of geological repositories, numerous national projects have been running for several decades. Many lessons can be learned from their setbacks and failures and many from their successes. The most advanced national programs in Finland, Sweden and France are nearing the operational phases. The technical lessons learned can be applied in further national programs and also in the case of an MNR.

However, although MNRs have been proposed many times over the past decades and there have been isolated examples of radioactive waste being transferred to another country for disposal[17], no concrete proposal for implementing a DGR that is shared between countries or that offers disposal as a service to foreign countries has yet been successful. As discussed below, lessons can be learned both from their interim successes and their ultimate failures. The history of MNR initiatives is well documented in the IAEA report, Cooperative Approaches to the Back End of the Nuclear Fuel Cycle: Drivers and Institutional, Economic and Legal Impediments, which is currently in production. This report points out that:

[17] See, for example, IAEA Tecdoc 1413

“The potential benefits of international or multinational control of the nuclear fuel cycle have been on the agenda ever since peaceful uses of nuclear energy were first considered. From the 1940s and 1950s through into the 1970s the primary driving force was control of nuclear weapons proliferation……. Proposals advanced from the 1990s onwards have moved forwards from the single focus of international control and now also address the environmental safety, societal and economic opportunities and advantages of cooperation on the back end of the nuclear fuel cycle.”

Over the past decades there have been some comprehensive studies of the viability of the MNR concepts, and a few detailed project proposals for implementation. Information is presented below on two of the most visible of these detailed projects. Both were disappointing in that the proposals did not lead on to implementation of the projects, but analysis of the reasons for this can provide useful lessons that may help optimize future projects. More encouraging signs of the attractiveness of the MNR approach are visible in the widening support for and participation in studies covering all key issues associated with the MNR concept. These are summarized in section A 2.2.2.

A2.2.1 Lessons Learned from Unsuccessful MNR Project Proposals

The most visible examples of proposed MNR commercial implementation[18] projects that have been unsuccessful are the Pangea project in Australia (which proposed a commercial disposal service), the more recent commercial proposals put forward by the Australian Royal Commission. Why have these initiatives not led to an implementation project? It is instructive to look briefly at their characteristics and at the challenges which each faced.

Pangea

Pangea Resources International (PRI) and its daughter company, Pangea Resources Australia (PRA), were set up around 20 years ago. The primary objective of PRA was to initiate a national Australian debate on the merits and drawbacks of Australia offering a commercial service for storage and disposal of SNF, HLW and LL-ILW from foreign countries. The broader aim of PRI was to internationalize Pangea’s specific ‘high isolation concept’[19] and to look at other potential siting regions. The concept focused on simple geological environments in highly stable, low relief, arid regions. Pangea argued that the high isolation repository concept, apart from offering an exceptional level of safety, could be less expensive to develop than existing designs requiring complex and expensive engineered barriers. The Australian initiative was supported by prominent members of the business and scientific community. It ran into problems when the extensive documentation being prepared for the planned public debate was prematurely made public. This led to a rapid loss of political support, and the project was dropped. The international efforts of PRI subsequently ceased when the key funder (British Nuclear Fuels Ltd) changed priorities and concluded that the commercial prospects for an international repository were too far into the future to justify the investment required.

Some positive aspects of the Pangea project were:

- The explicit quantification, in the scope of a full business plan, of the very substantial benefits that a country could receive through hosting on an MNR.

[18] The MNR studies of the Arius Association and the ERDO Working Group on shared repository concepts have remained at the conceptual phase, as yet. These are discussed in the following section.

[19] This concept was based on finding regions and settings that would allow simplified but highly safe repository designs because of the simple layered geological formations, low topographic relief and remote siting

- The strong support for studying the MNR option that was demonstrated not just by the business community, but also by prominent members of the scientific community.

In retrospect, the weakest aspects of the project were:

- The issue of nuclear power and the fuel cycle was even before the Pangea project highly controversial in Australia, with no nuclear power plants in the country and a majority of the public and politicians opposed to increasing involvement
- The attempts of the Pangea project funders to maintain confidentiality for an overly long preparatory phase, leading to early leaks to anti-nuclear groups
- The lack of ensuring some level of bipartisan political support in Australia
- The fact that the initiators of the project were commercial companies from outside Australia.

South Australia

Some years later, in 2015, a new Australian initiative was started in a framework that removed many of these negative characteristics of the Pangea project. The government of South Australia, looking for ways to stimulate the State economy, set up a Royal Commission charged with examining the business cases for South Australia expanding its activities in the nuclear fuel cycle, including the development of large-scale commercial, multinational waste storage and disposal facilities. The project involved technical and economic impact evaluations. Following the publication of the Commission's comprehensive report, the South Australian government set up a special agency to develop its response. The agency initiated a complex public consultation process involving stakeholder juries whose conclusions were largely predictable in advance from their selected participants. This culminated in a negative response from the final jury, based largely on objections from indigenous peoples and on questions raised about the financial risks that South Australia might have to accept. As a result of this setback, the State Government could no longer count on cross-party political support and ceased funding any further evaluation. The South Australian government continues to monitor developments on this topic, and the question of introducing nuclear power to the country is again being posed in Australia.

An important positive signal set by the South Australian initiative was that it is less controversial if the topic is broached in a "top-down" fashion by governmental bodies initiating a fully open public discourse. Further positive outcomes were the development and publication of relatively detailed implementation plans for a large MNR, together with confirmation of the potential economic benefits of hosting such a facility. Despite the projected economic benefits, opponents of the project argued successfully that the financial risks associated with initiating such a large-scale project were unacceptable. These arguments may have been countered had the project been able to demonstrate that a sufficient customer base was ready to make use of the facility. The failure to engage with potential user countries during the course of the study may be one of the factors that led to the initiative faltering. Assessing the credibility of a proposed MNR projects and judging the robustness of the business case put forward would be a much simpler task if some level of commitment to use the facility has been clearly demonstrated by a number of countries. Other important contributors were the complex decision mechanisms involving different stakeholder juries that entered into the process with preconceived objectives and the failure to win sustained bilateral political support.

The failure of these two comprehensive projects, as well as various less-developed proposals, to result in implementation of an MNR facility illustrates clearly that multiple challenges - mostly involving political and public acceptance but also including preparation of a convincing business case - must be overcome in moving the concept ahead. More encouraging indications of the ultimate feasibility of MNR development, however, can be gained from the growing acceptance of the MNR option into the mainstream of radioactive waste disposal planning, as exemplified by the studies referenced in the following section.

A2.2.2 Studies on the Benefits of the MNR Concept

Some of the earlier enthusiasm for multinational repositories, sometimes in the framework of regional nuclear fuel centers covering all aspects from fuel production through reprocessing to disposal, faded during the 1970s, 80s and 90s when interest in nuclear power was declining globally. This situation has now changed. Despite the setback resulting from the Fukushima accident, evermore countries are considering introducing nuclear energy – and this trend has intensified with the focus on reducing carbon emissions that can affect the global climate. The realization of how the lack of progress with implementing geological disposal has led to understandable opposition to nuclear power in countries that have been operating NPPs for decades has resulted in increased appreciation of the importance for newcomer countries of having credible disposal strategies.

Since the turn-of-the-century, the IAEA has repeatedly returned to the issue, producing a series of reports and initiating a number of working groups. The MNR concept has been addressed at a global scale in regional discussions in Europe, the MENA region and Southeast Asia[20]. The EC-funded SAPIERR projects[21] involved 14 European countries that together examined the options for an MNR in Europe. The results of the SAPIERR projects showed clearly that an MNR could bring economic, environmental, safety and security advantages. A specific outcome of the study into the feasibility of shared EU waste disposal solutions was the establishment of a new organization to explore and develop in more concrete terms the concept of shared repositories accepting wastes from a number of European countries. The Working Group on a European Repository Development Organisation (ERDO) engaged in European cooperation from 2009 to 2020[22] as a multinational working group whose members were organizations nominated by their governments, established to study the feasibility of setting up an organization that would implement one or more shared geological repositories in Europe. In 2021, the Working Group status of ERDO transformed into a legal association with a domicile and staff hosted at the headquarters of COVRA, the Netherlands Waste Management Agency. The RNFSWG of the IFNEC forum and World Nuclear Association working groups have also organized meetings on the potential benefits of MNR implementation, focusing on the practical steps that could be taken in the short time and also on the longer-term issues related to financing options. The INPRO group of the IAEA is also currently involved in a study on cooperation at the back-end of the fuel cycle. Specific studies have also been completed by various organizations such as the American Association for Arts and Sciences (AAAS)[23] and the Nuclear Threat Initiative (NTI), the Mansfield Foundation, the Stimson Foundation, the Nautilus Institute, and the Centre for Strategic and International Studies (CSIS).

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[20] McCombie C., Chapman N.A, Regional Cooperation on Spent Fuel Management Status and Prospects in Europe, Arab Regions and Asia, IAEA Spent Fuel Conference (2015).

[21] Chapman N.A., McCombie C. and Richardson P. (2008). Economic Aspects of Regional Repositories SAPIERR II Work Package 3. April 2008, www.sapierr.net/index_01.htm

[22] ERDO, European Repository Development Organisation (ERDO) Working Group, www.erdo-wg.eu

[23] Charles McCombie, Thomas Isaacs, Noramly Bin Muslim, Tariq Rauf, Atsuyuki Suzuki, Frank von Hippel, and Ellen Tauscher, Multinational Approaches to the Nuclear Fuel Cycle (Cambridge, Mass.: American Academy of Arts and Sciences, 2010); Stephen M. Goldberg, Robert Rosner, and James P. Malone, The Back-End of the Nuclear Fuel Cycle: An Innovative Storage Concept (Cambridge, Mass: American Academy of Arts and Sciences, 2012); Robert Rosner, Lenka Kollar, and James P. Malone, The Back-End of the Nuclear Fuel Cycle: Establishing a Viable Roadmap for a Multinational Interim Storage Facility (Cambridge, Mass.: American Academy of Arts

The successful efforts to involve many international organizations, think tanks and national programs in studies on the MNR concept are indicative of the wide recognition of the global, national and regional benefits that could result. One key lesson that can be drawn by the initiators of generic studies to date is that analyses made will be subject to intense scrutiny and must therefore be performed with scientific rigor and with transparency. Equally important is the conclusion that progress in projects is mostly very much slower than proponents initially have aimed for. As in the case of a national GDF, stepwise and adaptive approaches appear to be the only way forward.

A2.2.3 Conclusions Drawn from Previous MNR Initiatives

One prime lesson that can be learned from the long development of the MNR concept is that until now the time has not been ripe for a concrete implementation project. National disposal programs have progressed much slower than originally planned. Advanced national disposal programs that were then in a sensitive siting phase were concerned that the prospect of a multinational solution might negatively impact on their own progress. Small nuclear programs could postpone disposal preparations because of the relative ease of implementing safe long-term storage. Newcomer countries had more immediate challenges with choices of technologies and vendors. But attitudes have changed significantly today. All countries accept (and international bodies like the IAEA and the EC insist) that a disposal solution must be prepared. The MNR topic is part of the normal discourse on the backend of the nuclear fuel cycle.

When might a successful MNR implementation project be initiated? Evidence from the history of national disposal programs and for the repository implementation timescales foreseen in many countries indicates that countries can easily keep their dual track policy option open for a decade or more. At present, the most productive developments that can enhance the likelihood of eventual MNR implementation are:

- increasing the number of countries that formally include the dual track option in their national policy and the number of countries that are prepared to join an active core group of MNR advocates
- strengthening and expanding the cooperation between these countries for RW predisposal management activities, such as sharing of facilities for treatment, conditioning and storage
- strengthening and expanding the cooperation between these countries in all topics related to preparing for and implementing disposal facilities
- identifying and studying further in cooperation the open technical, economic and societal issues specifically in the context of the potential partner countries
- opening or intensifying discourse in their own countries on the public and political acceptability of participating in an MNR project as a user or host country.

A2.3 Examples of Functioning Dual Track Programs

This section provides details of four well-developed dual track programs in Europe: Slovenia, the Netherlands, Denmark and Norway.

A2.3.1 Slovenia[24]

Slovenia has a very small nuclear program: it co-owns one nuclear power plant with Croatia with a 50:50 share and it operates one TRIGA research reactor and a central interim storage facility for radioactive waste from small producers (medicine, industry and research). It has one approved location for a low and intermediate radioactive waste repository where construction is envisaged in 2021 and one closed and remediated uranium mine with 2 mining and hydro-metallurgical tailings disposal sites at Žirovski Vrh uranium mine.

In Slovenia, spent fuel is only generated by the Krško NPP and the TRIGA research reactor and is stored at the reactor sites. Irradiated fuel in the Krško NPP either is loaded in the reactor or stored in the spent fuel pool. All irradiated fuel in TRIGA is currently loaded in the reactor itself, since all the spent fuel from the TRIGA Research Reactor was returned to the USA in 1999. The quantity of spent nuclear fuel until 31/12/2020 is low (around 530 tonnes of uranium and 6.4 tonnes of plutonium). These volumes are exceptionally small compared with other nuclear states and will also remain so after both reactors cease to operate.

As Slovenia is a full member state of the European Union (EU), the implementation of the national radioactive waste management program according to the EU waste management directive referred to earlier is required. Slovenia has implemented this through its national legislative system, including the Ionising Radiation Protection and Nuclear Safety Act[25] and Resolutions on nuclear safety strategy and on waste management strategy[26].

In 2016, Slovenia adopted the second decennial revision of the national waste management strategy: Resolution on radioactive waste and spent fuel management for the 2016–2025 period (ReNPRRO16-25).

In this respect, progress made in international and regional efforts to draft a joint regional program on disposal is also to be considered.

ARAO promotes the concept and future implementation of sharing pre-disposal and disposal activities and facilities with partners in the international radioactive waste community. Slovenia is also involved in the work of IFNEC. The main reason for cooperation and integration in this area is Slovenia's extremely small-scale nuclear program which implies that participation in joint programs can achieve significant positive economic effects.

Specific elements of Slovenia's dual track program are summarised below.

To ensure uninterrupted operation and sufficient storage capacity in Krško NPP, a dry storage facility for spent fuel with a design lifetime of 100 years will be constructed. The construction of dry storage on Krško NPP started in 2021 and is scheduled to be operational at the end of the year 2022. After the period of dry storage, spent fuel or high-level waste generated from the Krško NPP decommissioning or spent fuel processing is to be further treated, packaged and disposed of. For spent fuel or HLW, a deep geological repository should be built to ensure adequate isolation of the waste from the environment.

The reference scenario for Slovenia's own repository in suitable hard rock geology was first developed in 2004 and revised in 2009 and 2019. It is based on the best available current knowledge of future inventories and the operation of all nuclear facilities in Slovenia. The national concept scenario includes the overall geological disposal program, including

[24] This material is based in part on an INPRO report in preparation.

[25] Ionising Radiation Protection and Nuclear Safety Act (Off. Gazette RS, Nr. 76/2017 and 26/2019)

[26] Resolution on Nuclear and Radiation Safety in the Republic of Slovenia for the Period 2013–2023 (Official Gazette RS, No. 56/13),

Resolution on the National Program for Managing Radioactive Waste and Spent Fuel for the Period 2016–2025 (Official Gazette RS, No. 31/16), research, development, and implementation activities for the siting, construction, operation, and closure of a geological repository. No site investigations for a deep geological repository have been carried out in Slovenia, and no specific data for geological disposal are available now. The reference scenario is made for a generic location in hard rock media. For some specific aspects, assumptions and estimates based on expert assessments were used.

Only direct disposal of spent nuclear fuel (no reprocessing) is envisaged, and the repository will be constructed in a hard rock environment at a depth of 500 m. The disposal concept follows the Swedish SKB KBS-3V model of disposal and includes at the repository site all structures, systems and components needed for the repository to operate as an independent nuclear facility.

In the national program, the beginning of national disposal of spent fuel is assumed to occur in 2065 or later. In parallel to a national disposal program, multinational disposal is possible. Both options work in parallel until the beginning of proposed construction of a national repository between 2055 and 2065.

In 2019, under the joint Slovenian-Croatian preparation of the Third Revision of the Krško NPP Radioactive Waste and Spent Fuel Disposal Program[27], a new reference scenario for a deep geological repository in hard rock was developed. For the purpose of cost analysis, it was assumed that the SF and HLW generated by Krško NPP decommissioning is managed jointly, first in dry storage on the location of the Krško NPP, and subsequently disposed of in a joint repository in Slovenia or Croatia. The two basic scenarios, both with Krško NPP operation until 2043, as was decided by the responsible authorities, are examined as follows:

- Base case scenario – start of regular operation of the SF repository in 2093
- Sensitivity case scenario – start of regular operation of the SF repository in 2065 as defined in the Slovenian ReNPRRO16-25

In the 2019 Revision, cost estimates are made for activities that can be carried out in both a national and a multinational approach, e.g., encapsulation in a regional encapsulation plant and disposal in multinational repository as well as several alternatives to the basic design.

Comparing unit investment cost for encapsulation in a regional encapsulation plant, it could be seen that the encapsulation joint venture partnership investment and services costs of larger encapsulation plants would be competitive and economically attractive when compared to the encapsulation costs for a smaller national encapsulation facility.

For disposal in a multinational repository two options are analyzed: Service concept and Cooperation concept. The Service concept assumes that a service provider country may develop a geologic repository which accepts SF from several customer countries (as was proposed in the South Australian approach), while the Cooperation concept is based on collaboration between partner countries in the joint venture project for development of disposal facility and construction of MNR in the host partner country.

Conservative cost estimates were made based on the Cooperation concept using total costs for the basic scenario (national disposal starting in 2093). These assume 5 partners (nations) deciding to construct one joint repository, with equal sharing of repository investment costs (conservative estimation) and allocation of operational costs dependent on the national inventory. The analyses indicate that unit costs for the Republic of Slovenia and the the disposal of their entire HLW and SF inventory decrease from1.25million USD/tHM to 0.66 million USD/tHM.

[27] Third Revision of the Krško NPP RW and SF Disposal Program, ARAO, Fond NEK, 2019

Slovenia has compared the costs of using a commercial service MNR concept with those of developing and using a shared multi-partner MNR. The South Australia Nuclear Fuel Cycle Royal Commission project evaluated[28] a commercial model for pricing SNF disposal services. A baseline 'willingness to pay' figure of 1.5 million USD/tHM was derived by the study. Taking account of the costs that a user would bear themselves in preparing and delivering the SNF to Australia for disposal, this was reduced slightly to produce a baseline 'price to charge' for disposal of 1.35 million USD/tHM. For Slovenia, the cooperative option, estimated to cost at around 0.66 million USD/tHM for 5 partners countries, could clearly be more favourable.

The reasons presented as to why Slovenia could be interested in using a disposal service and the factors influencing its decision and willingness to pay for this service are based on the technical expert bases for the preparation of the ReNPRRO16-25 and costs analysis performed for the comparison of different disposal scenarios in national, regional, or multinational facilities as presented above.

If Slovenia finally decides to dispose its SF and HLW in an MNR, it must be prepared to pay certain costs, principally including the costs for the interim storage and final disposal service provided. The ability and the readiness/willingness of Slovenia to pay for disposal services provided by a host country would depend upon the economic and social conditions prevailing in Slovenia and the service provider country. Rationally, the maximum price that a service user might pay for disposal services is governed by the costs of the alternative in developing a national disposal facility and/or costs of other potential multinational disposal options. In practice, the price set by the service provider will be compared with other options.

According to the current national framework for radioactive waste and spent fuel management in Slovenia a responsible management of SF and HLW will be continuously conducted to comply with its responsibilities and obligations under the Joint Convention. In parallel, international cooperation with other interested countries will be pursued toward shared solutions that permit those countries to meet their responsibilities and will analyze potential multinational disposal service opportunities. These will be analyzed and compared against results of studies for national geological disposal facility in hard rock or other disposal options with cost estimation.

[28] Jacobs-MCM report to Australian Fuel Cycle Royal Commission (April 2016). Radioactive Waste Storage and Disposal Facilities in South Australia. Quantitative Cost Analysis and Business Case. Available at: http://nuclearrc.sa.gov.au/app/uploads/2016/03/Jacobs-MCM.pdf

A2.3.2 Netherlands

In the Netherlands, radioactive wastes are generated by nuclear power production and by the use of radioactive materials in medical, research and industrial applications[29]. The nuclear program of the Netherlands is relatively small, but diverse. In the Netherlands, there is one nuclear power plant (NPP) in operation: the Borssele Pressurized Water Reactor. Another NPP, the Dodewaard Boiling Water Reactor, was shut down in 1997 and is now in 'Safe Enclosure', a stage of decommissioning. Furthermore, there are two research reactors in operation, and one on the Research Location Petten was taken out of operation in 2010. Its decommissioning is ongoing and spent fuel has been removed.

The total quantities of spent fuel and radioactive waste are modest. By centralizing most of the radioactive waste management activities in the Netherlands in one national WMO, COVRA, and at one site, benefits of economies of scale are gained. The storage capacity at COVRA has been dimensioned to handle the expected Dutch demand for storage capacity until at least 2130.

The Dutch policy on radioactive waste management is stable and for more than thirty years has assumed the aboveground storage of the radioactive waste for a period of at least 100 years, after which disposal deep below ground is envisaged in around 2130. The choice of location is not yet the subject of discussion. The definitive decision on this disposal method will be taken around 2100. At that time, society may opt for a different management option, depending on the state of understanding at that time, and assuming that other alternatives are available by that time. The relatively long period of above ground storage will provide time to learn from experiences in other countries, to carry out research and to accumulate knowledge. In this way, sufficient money can also be set aside to make eventual disposal possible. As a consequence, in the future, a well-argued decision on the management of radioactive waste can be taken, without unreasonable burdens being placed on future generations.

Due to the limited volume of waste and the high costs for disposal, one disposal facility is planned, in which all radioactive waste can be placed. The estimated costs for creating this disposal facility will be charged by COVRA to the suppliers of the waste. These costs will be charged for both low level and intermediate level radioactive waste, and high-level radioactive waste that will be stored in the disposal facility.

The funds provided will be invested so that they will be able to grow during the period of aboveground storage. The aim is to cover the costs for the preparation, construction, operation and closure of a geological disposal facility following the period of aboveground storage. The design of the long-term management will also be influenced by the volume of waste to be disposed of. A cost estimate for a disposal facility will be updated within the Research Program Disposal Radioactive Waste (OPERA, 2011-2016). OPERA is the third research program for geological disposal in the Netherlands aimed at developing a roadmap for long-term research into geological disposal in the Netherlands. With this in mind, safety cases are being developed for both rock salt and Boom clay. By periodically drawing up a safety case, research can be managed over a longer period of time.

In order to achieve actual disposal within this strategy, a national route towards disposal will be elaborated while, at the same time, the possibility of collaborating with other European Member States in establishing a disposal location will not be excluded. In the dual strategy currently being followed by the Netherlands, intensive international collaboration has been promoted through the ERDO working group, which transformed into the ERDO Association in 2021.

[29] National Report of the Kingdom of the Netherlands for the Sixth Review Meeting, October 2017

The Dutch national program for the management of radioactive waste and spent fuel[30] recognizes that creating a multinational disposal facility offers clear advantages. These include lower costs for creating the disposal facility, more choice of possible suitable locations, the combining of technical capacity and supranational supervision. Furthermore, for each disposal type, diversity can be achieved in waste types. There are also advantages in respect of the exchange of knowledge and innovations.

As described in the Dutch national program, the challenges facing a multinational disposal include the necessity to transport the radioactive waste over longer distances, deviation between (national) legislation and definitions, cost sharing among the partners, different timetables and locations from where the waste will be delivered.

A2.3.3 Denmark[31]

The bulk of radioactive waste in Denmark originates from the decommissioning of the former research reactors and supporting facilities at the Risø peninsula close to Roskilde, where all nuclear facilities in Denmark are located. Minimal amounts of experimentally irradiated spent fuel of power reactor type and fuel from one former research reactor are stored under safe and secure conditions at the Risø site by the operator of the nuclear facilities under decommissioning in Denmark, Danish Decommissioning.

Nuclear energy is not part of the Danish energy mix, and the annual generation of radioactive waste from users of radioactive substances in research, industry and the medical sector in Denmark is managed by Danish Decommissioning. NORM waste originating from the oil and gas-extractive industries resulting from maintenance and routine operations is managed and stored by the responsible licensees at their sites. Danish Decommissioning is also responsible for the safe and secure management of spent fuel and radioactive waste arising from the decommissioning activities as well as radioactive waste originating in the research, industrial and the medical sectors in Denmark.

In May 2018, the Danish parliament adopted resolution B90/2018 on a long-term solution for Denmark’s radioactive waste, specifying long term storage for up to 50 years of all radioactive waste and spent fuel followed by geological disposal no later the 2073. As a result of the adoption of parliamentary resolution B90/2018, a new national policy and associated program for the responsible and safe management of spent fuel and radioactive waste is to be established in compliance with Council Directive 2011/70/Euratom.

Parliamentary Resolution B90 specifies the end goals for management and disposal of these waste streams and defines the responsibilities of Danish Decommissioning as waste management organization in the framework of B90. The resolution aims to implement a long-term solution for Denmark's radioactive waste with a view to continued safe storage until the waste is placed in a disposal facility. In the short-term, the Danish Government proposes that the storage facilities at Danish Decommissioning are upgraded with the objective of storing radioactive waste under adequate conditions. In the medium term, geological studies should be performed at depths of up to 500 meters in order to identify possible sites for a deep geological disposal facility in Denmark. After this, a location of the disposal facility can be

[30] The national program for the management of radioactive waste and spent fuel: The Netherlands, June 2016 https://english.autoriteitnvs.nl/binaries/anvs-en/documents/report/2016/08/09/the-national-program-for-the-management-of-radioactive-waste-and-spent-fuel/the-national-program-for-the-management-of-radioactive-waste-and-spent-fuel.pdf

[31] the Parliamentary resolutionon a long-term solution for Denmark’s radioactive waste, https://ufm.dk/en/newsroom/issues/radio-active-waste/english-material, COUNCIL DIRECTIVE 2011/70/EURATOM FOR THE RESPONSIBLE AND SAFE MANAGEMENT OF SPENT FUEL AND RADIOACTIVE WASTE Second report from Denmark, 2018 COUNCIL DIRECTIVE 2011/70/EURATOM FOR THE RESPONSIBLE AND SAFE MANAGEMENT OF SPENT FUEL AND RADIOACTIVE WASTE (sst.dk)

recommended based on a number of analyses of geological, physical and socio-economic and safety conditions and implemented similar to solutions in Sweden, Finland and France, where facilities are currently being prepared.

Parliamentary Resolution B90 also allows for the Government to continue to explore possibilities for an international solution with regard to the disposal of special waste abroad, either through the export of waste via a bilateral agreement or through participation in an international disposal solution for long-lived radioactive waste. If an international solution for special waste cannot be realized before a decision is required on the project planning of a deep geological final repository in Denmark, the future planning must include disposal of special waste within Denmark.

With regard to possibilities for exporting special waste, which comprises spent nuclear fuel from Research Center Risø, the Ministry of Foreign Affairs has explored possibilities for exporting radioactive waste to selected countries during the period 2013-2018 but had to conclude that so far it has not proven to be realistic to export the waste as a result of legislative, technical, and/or political conditions in these countries. The competent Ministries last noted in 2018 that at present, there is no prospect for a multilateral solution for disposal of radioactive waste. Nevertheless, the Danish Government acknowledges that this could change and will continue to investigate possibilities for joint international solutions – including possibilities to export the most radioactive Danish nuclear waste to other countries with significantly greater amounts of radioactive waste and Danish Decommissioning will continue to participate in cooperation on any joint European solution under the auspices of the European Repository Development Organisation working group (ERDO-WG), now reorganized as the ERDO Association.

A2.3.4 Norway[32]

Norway has no nuclear power program but has had four research reactors at Kjeller and Halden, all of which are now permanently shut down. Nuclear activities in Norway started in 1948 with the establishment of the Institute for Atomic Energy, now the Institute for Energy Technology (IFE). The Norwegian oil and gas industry generates significant amounts of NORM waste.

The total inventory of spent nuclear fuel in Norway will be almost 18 tonnes, of which about 6.6 tonnes are stored at Kjeller, about 10.8 tonnes are stored at Halden, and almost 350 kg is still in the HBWR at Halden. The fuel in the HBWR core is not spent fuel as defined in the Joint Convention but will be spent fuel when permanently removed from the reactor. Some fuel has been returned to its State of origin, some fuel underwent reprocessing at the pilot plant at Kjeller, and some was reprocessed (and the products and waste retained) in Belgium.

In 2018 and 2019, IFE decided to permanently shut down its two remaining operational research reactors, HBWR at Halden and JEEP II at Kjeller. No further nuclear energy related activities are planned in Norway, and therefore policies and strategies are being developed to address the increasing focus on decommissioning existing nuclear facilities and managing the spent fuel and radioactive waste from these facilities. Some non-nuclear activities will continue to produce radioactive waste, but (except for NORM wastes) the amounts will be much smaller than those from nuclear decommissioning.

In 2018, the Government decided to establish the Norwegian Nuclear Decommissioning (NND) as a state agency to take over responsibility for decommissioning the research reactors

[32] National Report of the Kingdom of Norway to the seventh Review Meeting, October 2020

and other nuclear infrastructure and for management, storage and disposal of radioactive waste containing artificial radionuclides.

Technical assessments from 2018 indicated that it is likely that packaging and other disposal system features could be designed, and a disposal site found in Norway, suitable to allow safe direct disposal for the relatively small amounts of spent fuel concerned. Some previous evaluations have indicated or assumed that some of the spent fuel in Norway has characteristics that would make it unsuitable for direct disposal and therefore would require treatment to facilitate disposal. A further concept evaluation report was issued in 2020, including proposals for shorter-term management of spent nuclear fuel and possible options for treatment. The concept is under further consideration by the Government.

Spent fuel and long-lived waste unsuitable for disposal at Combined Disposal and Storage Facility at Himdalen will be stored until final disposal is possible. There are planned activities to improve the storage conditions with construction of a new storage facility and to increase storage capacity for spent nuclear fuel.

It is expected that new spent fuel management facilities will be needed in the near future, but no definitive decision on disposal of spent fuel has been taken and any decision will be in accordance will the strategy for radioactive waste management under development.

Norway keeps open the option of using multinational disposal facility and is a Member of the recently established ERDO Association. Given the small amounts of Norwegian wastes that need to be disposed of in a deep geological formation, there is special interest in the option of deep borehole disposal. NND is studying this approach in a national context and also sharing information of DBH disposal with its ERDO partners.

A2.4 Implications of Co-existing National DGR and MNR Development Programs

For a long time, there was a significant debate on how the concurrent existence of national and multinational programs might impact the probability of success of either.[33] This debate and some of the conclusions reached are documented in [34]. Tables A2-1 and A2-2, which are based directly on this report, summarize the positive and negative implications of co-existing national and MNR programs.

Table A2-1: Potential negative interactions and implications

Abbreviations: NP = national program; MNR = multinational repository; DGR = deep geological repository

Issue	Comments
Concern in host communities for a national DGR that it will eventually be opened up commercially to other nations	This has impacted negatively on some NPs in the past. Public debates have shown that avoidance of foreign waste can be a key requirement for achieving local acceptance. The operator of a DGR and the national government can give national assurances, if required, that the facility will not eventually be opened up for wider use. MNRs should also stress in their communications that no country can be compelled against its will to accept foreign wastes.

[33] McCombie c., Verhoef E., Chapman N., 2015. Towards A European Regional Geological Repository, WM2014 Conference, March 2 – 6, 2014, Phoenix, Arizona, USA14620

[34] Chapman N.A., McCombie C. and Verhoef E. (2011). Implications of Co-Existing National And Multinational Geological Repository Development Programs In Europe. In: Proceedings of 14th International Conference on Environmental Remediation and Radioactive Waste Management, ICEM2011, September 25th – 29th, 2011, Reims, France. ICEM2011-59118

International laws may force a NP with an operational DGR to accept waste from another European country	The IAEA Joint Convention states explicitly that "any State has the right to ban import into its territory of foreign spent fuel and radioactive waste". The EC Directive also keeps open the option of EU Member States sharing repositories.
MNRs may be presented as unethical because they conflict with the responsibility of a country to manage its own wastes	The Joint Convention states: *"ultimate responsibility for ensuring the safety of spent fuel and radioactive waste management rests with the State".* However, participation in a credible MNR may be one way of assuming 'ultimate responsibility'. Nevertheless, an MNR policy on its own is not a way to avoid the national responsibilities which the Join Convention lays down. The policy must be translated into a strategy and an RD&D work program, for which the financial means must be set aside. It is imperative that both MNRs and NPs are clear that advantage must not be taken of a host country in economic difficulties in order to solve problems of richer countries. All countries have a direct interest in ensuring that safety and environmental standards must be high for all repositories – whether these be national or regional.
Focus on MNRs may distract and slow down NPs at a critical time in their development	A concern of some NPs is that the prospect of a MNR becoming available elsewhere will reduce the national political support for a NP and – perhaps even the financial resources allocated to the NP. This is a conceivable consequence that must be addressed at the national political level. Clear communication of goals and timescales by both NPs and MNRs can help avoid this negative consequence. A dual track approach keeps both options alive.
The existence of MNRs may allow countries to take a 'do nothing' approach to their wastes, in the hope that a solution will be found for them	This is a substantial point, although it is noted that some NPs already have such distant tangible target dates that they amount to effective 'wait and see' policies, even though limited technical studies continue. Consequently, it is better for countries to be actively involved in a MNR that has a realistic schedule and siting program, than to have only a single-track NP with far future 'deliverable' dates. Active involvement will also enhance national know-how in the field of DGR development. As stressed above, participation in a MNR should require a strategy and an RD&D work program, for which the financial means must be set aside. Potential MNRs cannot be perceived as a way to avoid decision-making and allocation of appropriate program funding.
Each country should have a NP, regardless of whether it is involved in an MNR	The debatable point here is the necessary extent of the national activities in small nuclear programs. All other nuclear energy activities (reactor operation, enrichment, fuel supply, electricity supply, etc.) are carried out across national borders. The answer is for each country to have an active program of some sort. It does not matter whether they have a purely NP, are actively involved in an MNR or have a 'dual track' NP/MNR approach, provided the program is realistic, active and achievable. At a minimum, each country must have a clear disposal policy, implementable strategy, work program and financing mechanism.
Public criticism of MNRs can both undermine the MNRs and rebound to affect NPs	The main criticisms that have been made have inferred that MNRs are unethical (see above), or that there is no realistic hope of finding a willing host country/community. Siting is difficult for any program. MNRs will have a siting process that is very similar to that of most modern NPs – namely with volunteering or, at the minimum, informed consent being required. It is in the interest of both NPs and MNRs to support such a societally based siting process.

Table A2-2: Potential positive interactions and implications

Abbreviations: NP = national program; MNR = multinational repository; DGR = geological repository

Issue	Comments
Enhancing global environmental safety and nuclear security	Given the rising interest in introducing, extending or expanding nuclear power programs, it is in the interest of all countries to help ensure that accidents or malicious acts will not occur anywhere, to harm nuclear projects everywhere. A concern is associated with the security hazard presented by numerous, scattered storage facilities for used fuel and other wastes. While no DGR program (NP or MNR) can hope to solve this quickly, it is helpful to show that surface storage across numerous countries is not going to be an open-ended commitment.

	A combination of NPs and MNRs is the most certain way to achieve enhanced safety and security since small nuclear programs have no incentive and, often, no means to implement expensive DGRs for many decades.
An active MNR program for all wastes may reduce the concerns of citizens in all countries, independently of whether these countries are expanding, maintaining or reducing their use of nuclear power	Unsolved waste problems in one country are a negative weight on neighboring nuclear power programs, even if they have comprehensive fuel cycle programs of their own. One or more operating MNRs demonstrate that waste disposal concerns can be handled globally. All countries must be interested in ensuring that a safe long term management solution for all wastes is available for themselves and for all of their neighbors.
A credible MNR project can help NPs by taking the pressure of the 'foreign wastes' issue off them	The world needs solutions for all its long-lived wastes and most commentators acknowledge that this will only be possible if some countries share DGRs. The existence of a dynamic MNR project should demonstrate that its participants are taking their own problems in hand themselves and not planning on being a burden on other countries. It has been argued that MNRs should wait until the leading NPs demonstrate the credibility of geological disposal. Public and political support for deep disposal may increase once actual operation is being demonstrated in a few countries.
Active R&D in MNR projects will address topics faced by other NPs and vice-versa	Given the wide range of wastes that might have to be catered for in a MNR, it is likely that the necessary R&D program might usefully cover topics that are not currently the central concern of larger NPs. This should increase the opportunities for collaboration. A major MNR project could include a program that is large enough to enhance and possibly accelerate technical RD&D work in some areas, as well as contributing significantly to shared project costs. An active MNR program will also serve to counter the criticism from NGOs that wish to oppose nuclear power programs; an MNR would answer the legacy challenge.
Economic advantages for both NPs and MNRs	A large-scale MNR will have potential commercial technology transfer requirements from NPs. Much conceptual technology transfer for DGRs takes place non-commercially and WMOs have an interest in preserving this situation. Some NPs, however, already have commercial goals and a MNR may become a major commercial customer for technology from such advanced NPs. This could involve shared technology development. The stronger the MNR, the more focused and mutually beneficial such commercial interactions could become. Disparate, small NPs on widely varying time schedules are unlikely to represent equivalent opportunities for commercial technology transfer. In the broader nuclear technology area, assistance with the credibility of small nuclear power programs can help them expand and thus have commercial benefits for nuclear supplier countries that also provide other NPP technologies. Clearly MNR countries can benefit economically as users from economies of scale and as providers from operation of a commercial service A win-win situation could thus result from advanced NPs actually participating in the implementation of an MNR in another country.
Participation in a MNR will build know-how and competence in countries.	National experience shows that the road to implementation of a DGR can be long and that success at the end of any specific project is not guaranteed. The same will be true for MNRs. The experience gained in a MNR will also be advantageous should any country later resort to a purely NP, since it will develop skills in many areas such as nuclear, mining and civil engineering, environmental assessment, etc.

Based on this analysis, it can be concluded that no conflicts need exist and that symbiosis is possible. Common messages that can be espoused by proponents of either approach include:

1. To ensure high levels of nuclear security and environmental safety, every country needs a disposal solution for all its radioactive wastes. For countries with long-lived radioactive waste, this requires access to a DGR.
2. For a global solution, this will require a mix of both national and shared multinational projects, and it is essential that each country is actively involved today in one of these options, or in a dual track combination of both.

3. Some national DGR programs are very advanced; it is important that these are not hindered in any way since the demonstration that progress is being made is valuable for all waste disposal programs.
4. Countries which opt for a dual track approach should clearly communicate to their national publics, and also to the global nuclear community, their policy, program and timing.
5. Multinational repositories can only be sited in willing communities and nations, and in host countries that are able to provide the technical and regulatory framework that is necessary to ensure safety and security.
6. If all nuclear countries have a credible repository program (national or multinational) then successful national programs will no longer be concerned about the possible imposition of requirements to accept foreign wastes. National and multinational programs need to work together to achieve this objective.
7. There are clear strategic, economic and technical advantages to all types of programs working closely together to ensure timely repository implementation for all countries. The communication activities of the nuclear community should stress the complementarity between national and multinational disposal programs.

A2.5 Potential for Further MNR Country Participation

Not all countries have done as much as those described in section A2.3 (Slovenia, the Netherlands, Norway and Denmark), but many have taken first steps. The most obvious examples are the countries that have been Members of the ERDO Working Group over the past decade.

Practical steps have been taken by some other countries that have adopted a dual track approach or at least expressed interest about some kind of regional or multinational cooperation for disposal. Certain countries that are developing national repositories for high-level waste or spent fuel as a primary or preferred option and are already beyond initial planning with concrete siting or RD&D activities nevertheless remain open for sharing options either on a regional or multinational level. The Czech Republic is an example. Slovakia is another example of country with nuclear power and a formally adopted dual track policy[35] where the first priority is development of a national SF repository but, in parallel, international developments on shared disposal are monitored. The Slovak National Program for the development of international repositories states that it is expected that the economic as well as other benefits of such solution for the final stage of management of spent nuclear fuel will ultimately outweigh the geopolitical and social barriers that are hindering the practical implementation of such a solution.

Similar policies for shared disposal have been implemented in Bulgaria and Hungary where HLW and SF shall be disposed of on national territories, except in the case of an agreement for the use of a regional disposal facility in another country. Domestic and international developments concerning the back-end of the fuel cycle must be followed and, if necessary, must be incorporated into the national policy, while at the same time progress must be made on implementation of the planned activities for the site selection and later construction and operation of the national deep geological repository.

The dual track approach is not limited to Europe. The United Arab Emirates, as one of the recent countries that started a major nuclear energy program, is also committed to a dual track

[35] The approved “Strategy of the back-end of peaceful use of nuclear energy in Slovakia” and the “National Policy and National Program of spent nuclear fuel and radioactive waste management in Slovakia),

approach with an RW management strategy that involves developing a national storage and disposal program in parallel with exploring regional cooperation options. Mexico's strategy is to dispose of its wastes in the country, or alternatively, in an international co-owned, shared facility that can serve as a beneficial solution for countries that have small nuclear programs, especially if located in the same geographical area. This could be the case for Latin American countries pursuing nuclear power programs.

A2.5.1 Summary list of National Policies on HLW/SF Disposal, Export and Import

The overview of national policies in Arab region countries tabled in the main report is expanded here to include other countries that have been involved in discussions on the multinational repository concept.

Table A2-3: National policies concerning HLW/SF disposal with export and import regulations.

Country	Power Reactors (PR)[36], Research Reactors (RR)[37]	National Disposal Policy for HLW/SF	Export permitted	Import for disposal	Notes
Jordan	No PR yet, 1 RR	Considering Dual track; priority not defined yet	Yes (under certain conditions)	No	Member of IFNEC
Egypt	4 PR, 2 RR	-	Yes (under certain conditions)	No	Member of IFNEC
KSA	No PR yet, 1 RR	-	Yes (under certain conditions)	No	Member of IFNEC
UAE	4 PR, no RR.	Dual track; priority not defined yet	Yes (under certain conditions)	No	Member of IFNEC
Australia	No PR yet, 4 RR	National	Yes (under certain conditions)	Yes (under certain conditions)	South Australia Government established a Royal Commission which re-examined the possibility of hosting a commercial multinational repository. Member of IFNEC.
Austria	No PR, 1 RR	Dual track; RR fuel return to USA	No	Yes (under certain conditions)	Member of ERDO
Belgium	7 PR, 6 RR	Dual track; first priority national	Yes (under certain conditions)	Yes (under certain conditions)	

[36] https://pris.iaea.org/PRIS/home.aspx, included power reactors under construction.

[37] https://nucleus.iaea.org/RRDB/RR/ReactorSearch.aspx?filter=0

Bulgaria	6 PR, 1 RR	Dual track; first priority national	Yes (under certain conditions)	No	Member of IFNEC Was Member of ERDO-WG
Croatia	50% of 1 PR,	Dual track, second priority national	No, unless differently prescribed by international agreements	Yes (under certain conditions)	Member of ERDO
Czech Republic	6 PR, 6 RR	Dual track; first priority national	No	Yes (under certain conditions)	
Denmark	No PR, 3 RR	Dual track; second priority national	Yes (under certain conditions)	Yes (under certain conditions)	Member of ERDO
Hungary	4 PR, 3 RR	Dual track; first priority national	Yes (under certain conditions)	No	Member of IFNEC
Ireland	No PR, no RR	Not defined yet	No	No	SF take-back or MNR as disposal option Was Member of ERDO-WG
Italy	4 PR, 16 RR	Dual track; second priority national	Yes (under certain conditions)	No	Member of ERDO and IFNEC
Lithuania	2 PR, no RR	Dual track; first priority national	Yes (under certain conditions)	No	Member of IFNEC
Mexico	2 PR, 4 RR	National, open to regional or international disposal	Yes (under certain conditions)	No	
Netherlands	2 PR, 8 RR	Dual track; second priority national	Yes (under certain conditions)	Yes (under certain conditions)	Member of ERDO and IFNEC
Norway	No PR, 4 RR	Dual Track			Member of ERDO
Poland	No PR, 6 RR	Dual track; second priority national	No, unless international agreements exist	No	Member of ERDO and IFNEC, nuclear power program development approved
Romania	2 PR, 5 RR	National	Yes (under certain conditions)	No	Member of IFNEC
Slovakia	9 PR, no RR	Dual track; first priority national	Yes (under certain conditions)	No	Was Member of ERDO-WG
Slovenia	50% of 1 PR, 1 RR; 2nd PR planned	Dual track; second priority national	Yes (under certain conditions)	Yes (under certain conditions)	Member of ERDO, IFNEC,
Switzerland	6 PR, 6 RR	Dual track; first priority national	Yes, only under an international agreement	Yes, only under an international agreement	

A2.6 Conclusions on Dual Track Experience

The progress, acceptance and development of shared disposal has in recent years been accelerated in many countries that have either officially adopted the dual-track policy or expressed interest for sharing disposal. However, little has been done on the concrete planning, siting and other necessary activities for its implementation. No country has really initiated a public debate on the MNR issue – especially a debate that includes the siting question. The proposed nationwide debate planned in the Pangea project was cut short by the premature publication of the detailed information being prepared as input. The later South Australian study attempted to organize a transparent and open debate, but the chosen public consultation approach was not optimal. The issue of whether a country participating in an MNR study should or must also be prepared to be considered as a potential host is sensitive, especially since in many countries (including Jordan) the import of spent fuel or radioactive waste is currently prohibited by law.

Nevertheless, as in all other environmentally demanding infrastructure projects, and with similarities for hazardous waste management, steps towards shared disposal should be well prepared, openly documented and focused at first on implementing shared predisposal activities and facilities that could later evolve in sharing disposal. Until then, countries should in parallel develop their own national plans and projects to operate a national repository program in a complementary manner with work on shared solutions.

Appendix 3 Looking Ahead to a Potential MNR Implementation Phase

The primary objective of this report is to present the advantages to Jordan that would result from adoption of a dual track policy aimed at retaining flexibility by including use of an MNR as a back-end option. Progressing further to future participation in an implementable project would require consideration of many further issues related to project development including financing and contracting. In addition, important further technical issues, such as development of a transport infrastructure, would clearly have to be addressed when considering participations in an MNR implementation project. Since these do not have direct impacts on the current dual track policy decision, they need not be studied in detail at the present development phase, they are not covered in the following discussion. However, for the awareness of policy makers, Appendix 3 addresses, at a broad level, key planning issues that would be involved in a potential future project.

A3.1 Funding Mechanisms for RWM and Disposal

Ensuring that any disposal program, national DGR or an MNR can be funded through to its completion is essential to guarantee the safe, long-term management of spent fuel and high-level radioactive waste. This is recognized in the Joint Convention, which states that *"Each Contracting Party shall take the appropriate steps to ensure that…adequate financial resources are available to support the safety of facilities for spent fuel and radioactive waste management during their operating lifetime and for decommissioning"*. The most common funding sources are the waste generators through the implementation of the polluters pays principle and the State providing its share or full funding for managing RW generated outside validity of this principle. Selecting the most suitable funding mechanism depends on many factors, such as the nuclear strategy and policy of the State, the disposal option, the legislative background and the institutional framework. In this regard, there is almost no difference establishing and ensuring funding mechanisms for an MNR or national DGR.

The most straightforward method to fund the final disposition of spent fuel is through a surcharge on electricity sales, which is consistent with the "polluter pays" principle and has no need for governmental budgetary allocations. Even though the surcharge is small, funds accumulate significantly over the life of the asset. Such assessments are often based on an assumed operation life of forty years for a reactor. However, with the current Gen II fleet already receiving life extensions to 60 years, and further extensions possible, a total operating life of eighty years is not out of the question.

A number of issues follow from dealing with a long-lived asset:

- When should the surcharge be assessed, given the timing of collections relative to actual use?
- Does it make sense to start collections in the early years of operations?
- How should the funds collection be processed and controlled?
- How should the funds be segregated?
- How should the funds be invested?
- What happens if the reactor has a premature shutdown, such that it does not operate for the assumed asset life, thus creating a shortfall in the funds reserved?

With the emergence of SMRs, the operating life of designs might be different (i.e., shorter), which will require adjustments in the formula, depending on the assumed design life of the asset.

For countries that have not previously assessed a surcharge on electricity sales, the government involved becomes the ultimate funding source for the national GDR. In this case, the funding obligation would need to be transferred to the MNR concept.

Regardless of how the funds are set aside, a timing issue remains related to the planning of the MNR: funds need to be available to develop the project, the nuclear infrastructure (including regulatory elements) to support it, and for the EPC (engineering, procurement, construction) function to deliver an operating facility. Development funding is inherently different from the financing for the project itself (which would include EPC costs), and this difference would need to be addressed in any funding and financing plan.

How funding is sourced is also a function of the structure of the project itself:

- Is the host country developing the project with its own financial resources, and then charging a fee for usage? Or are participants taking *pro rata* ownership interests in the project (with the corresponding obligation to support the project with development funds)?
- How does a participant demonstrate its financial capacity?
  - Should funds be pooled into a trust fund that is centrally controlled by the MNR development organization?
  - Must the obligation be cash collateralized, or would a government guarantee suffice?
  - Is there a minimum surcharge that a participant must assess in order to be eligible?
  - Can funds reserved under the surcharge mechanism be used for development costs, under a co-ownership structure?
  - How can the project be protected from a participant's funding default?
  - Is the MNR ownership or participation fee based on a reserved capacity or actual usage?

A3.1.1 Recommended Approaches for Assuring Funds

- A potential MNR participant should reserve the necessary funding based on surcharges for electricity sales.
- Surcharges to cover future disposal costs should be based on the assumed cost of a domestic DGR as that would be consistent with a "dual track approach. (In many countries surcharges also cover decommissioning costs for which a separate segregated fund can also be established).
- An MNR structure should be able to utilize funds already accumulated, with further accounting for funds from future operations.
- Funds should be segregated. Ideally, they should be transferred to the equivalent of a managed trust that acts for the benefit of the MNR project.
- If the participating country were to withdraw from the project, the trust would return the participant's share of unused funds (in accordance with the terms of the participation agreement).

- Countries that have funds already set aside will probably be subject to a “first in, first used” situation, but that will benefit the project by reducing the need to source development funding.
- Ultimately, the project model has to account for development, construction, and operating costs, basing the fee or ownership interest on those estimates. Significant contingency will be needed to account for schedule delays and cost overrun; however, the net savings should still be shared *pro rata*, with the host country possibly receiving extra benefits because of its readiness to act as host[38] and also to include funds for the local benefits that will need to be created to build public (especially local) support.

A3.1.2 Availability of National Funds for a National or MNR Project

As noted above, the most assured approach to the creation of funds will be the assessment of a surcharge on electricity sales during NPP operation, with the accumulation of revenues in a segregated fund, combined with reasonable, conservative investment strategies. Prior to committing to an MNR, these funds would remain with the potential MNR participants. However, at some point during the progress of the MNR project, these funds would need to be transferred to the MNR owner/operator, in order to support project development. Until the MNR is in operation, the participating country would need to have the right to withdraw funds from the account, if the project does not make adequate progress and the participant wants to revert to a domestic approach. Once the MNR is in operation, the nationally-sourced funds would be transferred per the participation agreement, whether as an ownership interest or as a usage fee.

Absent the reservation of funds (through surcharge), a potential user of the MNR might be relegated to a customer role, unless the participating government wants to contribute funds to take an ownership interest. Similarly, if funds have not been already reserved (through surcharge), then a government contribution might also be needed to reserve space in the MNR, depending on the ownership / fee structure. National legislation would need to allow for transfer to the MNR at some point.

A key issue on use of national funds (assuming proper legislative authorization for use for the MNR) is one of timing. The MNR owner/operator will need to consider funding structures that account for countries at different stages of funds accumulation through operation. Such structures could also be a function of the nature of the participants themselves, recognizing that:

- the more participants that have already accumulated funds, the easier it will be to use such funds for project development and the EPC contract, thus placing less burden on government contributions (especially the host government);
- the more participants that are newcomer countries, the greater the need for government contributions and external finance;
- if there is sufficient ability to source funds in the near term, then it could be easier to scale the MNR to allow for extra space that would allow the entrance of additional participants and thus enhance the likelihood of a successful commercial / profit approach for the facility.

For Jordan, it will be necessary to decide the manner in which it wishes to participate in any proposed MNR, whether as customer or partial owner, recognizing that the latter would require an earlier contribution of funds to the MNR project and would therefore place greater emphasis

[38] In English financial jargon, this is sometimes referred to as “sweat equity”

on an earlier use of government-budgeted resources (as opposed to funds accumulated from operations).

As a final note, it could serve as a confidence-building measure for viability of the project if participants have similar approaches on the accumulation of funds through electricity sales, including the rate at which this is done. Nevertheless, the ultimate specific requirements of the MNR project agreement will determine what is owed by a participant. Realistically, absent an assured approach on the accumulation of funds, there will be a greater need for government direct support or government guarantees.

A3.2 Considerations Determining Participation in a Specific MNR Project

Adoption of a dual track approach is an important policy decision. It would have implications on the radioactive waste management program of Jordan. However, the immediate impacts on personal and financial resources are limited. The timescales for development of national repositories have shown clearly that development of a specific project takes many decades and the major investment decisions on participation in such a project will not be taken for some time. Adopting a dual track policy and cooperating with partners in developing the MNR concept does not imply a prior commitment to participate in any specific MNR implementation project. The decision basis for such future project participation would require a much deeper overall strategic assessment including:

- Timing of the project, relative to Jordan's needs[39];
- Cost of the project (participation share or fee), relative to Jordan's means;
- Overall quality of the project, both technically and reputationally.

As Jordan considers various options, the strategic assessment will also consider whether the project is regional or multinational that is "out of region". In considering the former, coordination with other civilian nuclear nations (existing or soon-to-be) in the region, such as the United Arab Emirates, Saudi Arabia, and Egypt, is to be expected. "Out of region" options will need to consider transportation costs and transportation routes, among other things.

In considering the costs, benefits, and risks associated with regional and "out of region" options, items of particular focus will be:

- Total cost of participation (balancing, for example, higher transportation costs to an "out of region" MNR against the lower membership costs of an "out of region" MNR that might support a wider range of participants);
- Safety and security profile of the proposed site (including transportation routes and methods);
- Viability of the proposed site and host country;
- Development schedule of proposed site;

[39] The optimal timing of an MNR will vary for different potential user countries. Some countries already have accumulated a considerable amount of SNF and funding, some others are just introducing nuclear power and will require SNF disposal in decades from now. So, the time difference could be almost 60 years. For the case of Jordan and potential regional MNR development this is probably not so important as in regional partnering countries nuclear power programs are almost at the same level of development as in Jordan.

- Level of influence in project development (i.e., might a regional approach be more conducive to active participation by Jordan and be a more effective means of protecting Jordan's interests?)

A3.3 Framework Required to Participate in an MNR Project

For any country to participate in an MNR project, several matters would need to be addressed. Some, but not all, of these are issues that also need to be addressed in the framework of a national repository project.

1. General policy authorization to participate in discussions on an MNR
2. Appropriation of funds to support development of the MNR (if intending to be a co-owner)
3. Authorization of funds to support delivery (EPC, etc.) of the MNR (if intending to be a co-owner)
4. Authorization of funds to pay all fees associated with the MNR (if intending to be a customer, noting the possibility of a reservation fee that precedes usage)
5. Method of reserving and investing funds from surcharge on electricity sales
6. Policy, legal, and regulatory adjustments to allow for shipment of RW / SF out of the country
7. Policy, legal, and regulatory adjustments to transfer title to the RW / SF
8. Policy, legal, and regulatory adjustments to allow for transfer of custody of the RW / SF to the transporter
9. Policy, legal, and regulatory adjustments to address liability issues concerning RW / SF
10. Insurance framework for the MNR and transport of RW / SF to the MNR
11. Policy decisions as to:
    a. Desire for retrievability of the SF
    b. Role in MNR (co-owner versus customer)
12. Policy decision as to time of the latest date for choosing MNR path of "dual track" approach
13. Commercial decisions as to:
    a. Break-even point on an MNR path (as opposed to a national DGR). This is the point where the MNR is viewed as a more favorable economic option for the participating country, as compared to the cost of a national DGR. To arriving at such a point, the country will need to have done sufficient analysis on both branches of the "dual track".
    b. Inflection point on an MNR path (as opposed to a national DGR). This is a key moment in the "dual track" approach, as it represents a time when money is additionally spent by continuing to pursue both tracks. This could be a moment when major expenditures need to be made on a national DGR. Note that it will be easier to determine this "inflection point" if an MNR is already in operation or at least at the same development/implementation stage as the national DGR project, as the costs and structure for participating in the MNR would be clearer.

Having to fully commit to an MNR in development is riskier and more speculative, which puts more pressure on when the “inflection point” occurs.

c. Rights and remedies under any contractual arrangements.

d. Ability / willingness to provide government guarantees for commercial / contractual obligations.

e. Issues concerning a defaulting participant (e.g., impermissible departure; failure to fund its commitments).

14. Regulatory review of standards that MNR must meet, including regulatory / policy review of standards for host country criteria

15. Regulatory review that MNR actually satisfies the national requirements before any transfers of wastes

16. Alignment of country needs with acceptance criteria of the MNR (e.g., fuel type, containerization, etc.)

Note that any references to policy, legal, and regulatory actions assume that such a process is structured and can be done in a time frame that supports the MNR project development schedule. However, it must be recognized that issues involved in participating in an MNR need to be agreed among all key stakeholders within the prospective participating country. Ideally, decisions would be based on technical assessments, and the legislative and regulatory actions would be formalized procedures. Nevertheless, it must be recognized that such decisions might not be “mere formalities”, so that there could be a risk to project participation if these matters are not managed properly.

Furthermore, the analytical framework would be conditioned upon / impacted by the ultimate role that Jordan wishes to assume in an MNR project. Whether to have an ownership interest or only be a fee-paying customer would have a dramatic influence on how Jordan approaches these issues; consequently, establishing a preferred national position earlier in the process will serve to inform all further thinking on the MNR path of the “dual track” approach.

The ultimate customer agreement will address capacity and usage fees, including all matters relating to participation (e.g., containerization, transport, custody/title, rights and remedies, exit rights / off-ramps.). A key consideration will be whether the fees are “locked in” prior to commencement of operations – essentially, are cost overruns passed through to fee payers, or are those overruns a pure equity risk?

A3.4 Contractual Implications of a Large, Complex Project with Foreign Partners

An MNR could follow four potential models:

- Model 1: A project developed by a host country alone, where other countries are purely customers;
- Model 2: A project developed by a host country alone, but where other countries are co-owners;
- Model 3: A project developed jointly by a number of countries, where each participant helps to develop the project in cooperative fashion, with each participant as a co-owner;
- Model 4: A project developed cooperatively along the lines of Model 3, but with a participant having the option to be simply a customer of the facility.

Models 1 and 2 fit within the "commercial approach" to an MNR referred to as option 3a in section 2.1 of the main report and models 3 and 4 are variants of the option 3b described there as the sharing approach.

For the purpose of this discussion, there is no expectation that a purely private (i.e., corporate) developer leads an MNR project. This position is based on the sensitivities around the MNR concept which are likely to necessitate government-sponsored leadership for development purposes, even if a private entity were ultimately to be formed to hold the ownership/operating interest of the project.

A3.4.1 Host Country as Developer

Under Model 1, the host country would take full responsibility for development, including all the financing aspects discussed in the present section. It would take full responsibility for the financing structure for EPC and other owner-related costs.

To offset this development risk, it would be expected that the host country would want to have assurances that a minimum threshold of client countries would participate, thereby justifying the sizing of the facility and the financing costs to support it. Such an agreement (a "Customer Agreement") would need to be legally enforceable, particularly with regard to the amount and timing of fee payments from the client country. For sizing / facility design purposes, it would be presumed that the client country would reserve an amount of space within the MNR, paying both a reservation fee and then a usage fee, as spent nuclear fuel is disposed. The reservation fees and usage fees would be commercially driven. Also, given the time value of money, and the high development and capital costs to get the facility into operation, the host country would want to front-load its revenue to the maximum extent possible. Such front-loading revenue to offset the front-loading of costs creates an inherent tension between owner and customer.

A key question will be when the reservation fee is paid, recognizing that payment of the reservation fee will be easier for customer countries that already have been collecting funds for a DGR, based on surcharges on electricity sales from operating nuclear power generation unit(s). If the host country can collect such fees during development and construction of an MNR, it will be able to reduce financing costs, which can improve the overall financial model for the project. Such savings could be shared with those countries that are able to pay the reservation fee during this time. As such, the host country might want to stipulate the manner in which a customer country reserves funds, as well as require certain milestones by which the necessary legal and regulatory frameworks are put in place by the customer country.

The Customer Agreement will also need to contain protections for the customer country in case the project runs over budget and/or is behind schedule. The opening position of a customer would be that the owner takes all such overrun risk. In addition, the customer will want protections if the project is never completed, in which case it might expect a return of some, if not all, of the funds contributed under a reservation fee approach. The customer will most probably also want the Customer Agreement to include inspection / oversight provisions, especially if payment of the reservation fee is prior to operation of the MNR.

The Customer Agreement will require lengthy negotiations, which will be particularly challenging at such an early stage of the project. In addition to the key issues of pricing policy, the key aspects will include:

- Security / Credit Quality on the source of fees (with the possibility of government guarantees);
- Enforceability of contractual commitments (including governing law and dispute resolution, with the customers expecting neutral law and international arbitration to create an unbiased structure);

- Remedies for host country defaults / project failure (with the expectation of a sovereign guarantee)

Three important questions remain:

1. Should a customer country ever be able to withdraw from the project? If so, when might it be allowed? If so, what would the financial penalty (if any) be?
2. Would a customer country be willing to pool electricity surcharges into an account that is not nationally controlled (i.e., something akin to an escrow account or a third-party managed fund)?
3. Would customers want a facility that allows for retrievability of fuel? If so, under what circumstances would retrievability be permitted?

A3.4.2 Participating Country as Co-owner

Under any Model 2 or 3 situation where a country is a participating owner, it would be party to a development agreement and to a participation / shareholder agreement.

Five preliminary issues exist in any co-ownership structure, which could influence (i) whether such a structure is of interest to a potential owner participant; and (ii) which contractual arrangements should be associated with such participation:

- Is the MNR a profit-making endeavor, or is it designed as an "at cost" partner project?
- What voting rights should each co-owner have? In particular, should the host country have any special voting rights?
- What is the timing and magnitude of financial contributions to the project, particularly during the development period? Specifically, should a development company be formed, which has different funding mechanics prior to the EPC Contract / Final Investment Decision? Should the development company have any responsibility for certain host country-specific issues relating to program infrastructure that are not direct project costs?
- Will each co-owner hold an equal share in the project, or will ownership interests be *pro rata* to need-based usage? Will the host country have a more heavily weighted interest? Will it get any special financial advantages by virtue of being the host?
- Under a co-ownership structure, will the MNR be made available to additional countries that are simply customers (and not co-owners) or does every participating country have to be a co-owner?

The development agreement could enable the co-owner to have a greater influence on the overall development of the project, including issues such as:

- Sizing of the facility, relative to financial return (i.e., Should initial co-owners over-size the facility to allow for future participations, which could enhance the returns on the investment?).
- Pricing of interests
- Exit ramps from project participation.

A3.4.3 Participating Country as Customer (i.e., Fee-Paying Client)

For Model 4, the country as customer, there are five fundamental issues:

1. What is the cost of participation compared to other options? This does not involve only a comparison of net present values (NPV) for national and multinational approaches. Lost opportunity costs to customer countries are also important. Even if the NPV of the MNR is lower, the potential customer must consider whether it would it be better to invest accumulated funds nationally for constructing and operating national DGR and to support local RD&D, create jobs, local infrastructure, etc.
2. When must I contribute money?
3. How do I have enough certainty / contractual protection to choose this path of the "dual track" approach? Do I have sufficient rights that protect my interests?
4. When am I "locked in" as a client?
5. Does this facility comport with "international best practices"?

If these five issues can be adequately addressed, then the country may choose to become a customer (noting, too, the additional intangible benefits of not having to dispose permanently the radioactive waste / spent fuel in its own country, thus avoiding a host of issues).

Given the aforementioned expectations of the host country, the customer will need to recognize that binding commitments will be needed, which, naturally, would be preceded by a significant level of effort by the customer country in assessing the MNR endeavor. At some point, once the customer country has done the appropriate level of diligence, it will face a "go / no go" decision, which will coincide with execution of binding contractual obligations.

Depending on the level of development of the MNR project, the contractual obligations might change. At an early stage, the customer country could enter into a development agreement – even as a fee-based customer – recognizing that the customer country would have its greatest amount of leverage at this point, as the project is in formation and the equity developer(s) might be trying to achieve a certain "critical mass" before going forward.

Ultimately, though, as fee-paying client and not owner, the client country will have less influence on the project, relative to its role if it were a co-owner.

The ultimate customer agreement will address capacity and usage fees, including all matters relating to participation (e.g., containerization, transport, custody/title, rights and remedies, exit rights / off-ramps, etc.). A key consideration will be whether the fees are "locked in" prior to commencement of operations – essentially, are cost overruns passed through to fee payers, or are those overruns a pure equity risk?

A3.4.4 Contractual Issues of General Applicability

For any MNR project to succeed, commitments need to be binding and legally enforceable. One of the greatest concerns is the impact of a member withdrawing from the project. If the economics and financing are based on a certain number of participants, then the impact of a departing member could be significant. The departure could be through a pre-determined exit ramp that is built into the project agreement, or it could result through a breach of the project agreement. In the latter case, the other members might wish to terminate the breaching member, or the breaching member may have simply abandoned the project.

Substantial thought will need to be given to the negotiation of remedies provisions within any contracting structure. A participant will need to consider the practicalities / enforceability of such remedies – i.e., would I really exercise this remedy, if the situation arises? Is the remedy enforceable (and in a timely fashion), as practical matter? Will this remedy adequately address my exposure (and loss)? A participant will need to consider that the remedies available might not provide complete coverage for the impact of the event suffered. In particular, in the case of a departing participant, the remaining participants might need to assume additional obligations, in whole or in part, recognizing, too, that the immediate need for funds for the

MNR project might override the need to recover funds from the defaulting participant (possibly not paid until after the dispute resolution mechanism has run its course).

A3.5 An MNR Project Development Plan (PDP)

To illustrate the steps that could lead to involvement in and utilization of an MNR, if and when a viable project arises, a suggested Project Development Plan is presented below.

- For the purpose of the Plan, it has been assumed that the country in which the MNR is located will determine the nuclear liability regime that governs the MNR. Jordan's expectation would then be that the licensed operator would be the party to which all third-party nuclear liability in channeled.
- Nevertheless, this does not resolve how such an exposure is allocated among participants. Jordan would expect that the third-party nuclear liability exposure of the MNR (as well as any liabilities associated with transportation of the spent fuel to the MNR) is fully insured through insurance pools. The cost of such insurance will have to be considered as part of the total ownership or participation costs of each country participant, and this would in part determine Jordan's willingness to pursue an MNR option.
- With these considerations in mind, Jordan would see several preconditions to the ultimate viability of the MNR endeavor (and Jordan's willingness to participate):
    1. The host country for the MNR must be a party to the applicable international conventions on nuclear liability;
    2. Nuclear insurance must cover channeled liability of the operator of the MNR;
    3. Nuclear insurance must cover all transport liability, if Jordan retains ownership of the spent fuel until arrival at the MNR site (or port/point of entry in the host country of the MNR);
    4. If Jordan were to retain an ownership stake in the MNR, then all insurance costs would be shared in proportion to each owner's ownership interest in the MNR;
    5. If Jordan were to be only a customer of the MNR, then all liability would cease upon transfer of custody of the spent fuel to the MNR.

A3.5.1 Detailed Plan

The PDP represents a stepwise approach for Jordan to consider the MNR path of the "dual track" approach. It is a series of activities (sequential in part) that need to occur and demonstrate meaningful progress on the MNR project.

At some steps in the PDP, Jordan would have the opportunity to provide inputs into the process. As elements of the PDP are completed, Jordan will be able to get a clearer picture of the potential MNR project. Failure to achieve elements of the PDP would serve as a sign that the MNR endeavor is either not viable or questionable. Less certainty on the MNR would then place greater emphasis on the domestic DGR option.

Certain elements of the PDP could be woven into contractual commitments as major milestones from which funding contributions and exit ramps could be designed. Elements of the PDP are as follows:

1. Convene series of meetings (first technical then followed by higher government officials) with countries potentially interested in an MNR approach.

a. It is expected that multiple meetings would be needed with the appropriate level of solicitation in advance, possibly a small number of "core countries" that could serve as the convening authority.

b. These would be working meetings with a sufficiently high level of representatives from each country, such that meaningful discussions could take place.

c. Each meeting would be preceded and followed with intervening work enabling clear and significant progress.

2. Agree with potential participants on the minimum requirements and other threshold issues for viable host country including:

    a. site conditions / suitability
    b. political stability
    c. physical security (both national and regional)
    d. safeguards
    e. site location and logistics
    f. public support
    g. environmental sustainability
    h. regulatory competence
    i. country credit rating
    j. ease of doing business
    k. corruption index score
    l. level of nuclear experience

3. Agree on a process for identifying potential host countries for the MNR (e.g., the simplest options would be if one or more countries at the outset express their potential willingness to host the MNR). Given the political sensitivity of this decision, it is possible that some or all participants may prefer to leave this open until preliminary studies of the factors listed in step 2 have been completed. Clearly, if all participants have a firm policy allowing only export of SNF, then no credible MNR project can be initiated.

4. Work with potential host country candidates to address their specific needs:

    a. Cost/benefit analysis; SWOT[40] analysis
    b. Country-specific challenges
    c. Key issues for resolution

5. Consider potential commercial structures for the project

    a. Is it "for profit" or an "at cost" endeavor?
    b. Will it be sized for future additional users? If so, how will future additional users be integrated into the commercial structure?

6. Conduct a "Lessons Learned" analysis

    a. "Lessons Learned" will draw from both positive and negative experiences on DGR efforts. Representative experiences will be from both prior MNR efforts and prior & current DGR efforts at the national level

[40] Strengths, Weaknesses, Opportunities, and Threats.

b. Analysis should consider non-nuclear projects:
    i. Megaproject analysis
    ii. International regimes on non-nuclear hazardous materials (Basel Convention)
    iii. Other cross-border projects involving cooperation between / among participating countries (e.g., hydroelectric projects; pipeline projects)
c. Outputs from the "Lessons Learned" analysis should be integrated into the Project Risk Register and into all execution planning
d. This activity would include visits to DGRs (and could involve participants from both the project management organization and representatives from country project participants)

7. Develop a Project Risk Register. This will first be a preliminary assessment and, as such, it will be regularly updated and serve as a management tool for the project team and the ownership group. A preliminary example of such a Register is included in Section A3.6,
8. Prepare a program of transparency and communication activities and key decisions for responsible stakeholders in countries potentially interested in an MNR approach
9. Establish key personnel for the development organization. It would be most efficient to have, at a minimum, a secretariat that would manage / oversee activities and perform key integrating work.
10. Establish overall development schedule and budget
    a. Development schedule should show activities through completion of construction / commencement of operation (noting that projections on construction and operation are preliminary at best)
    b. Initial budget should be for development period only
    c. Initial budget should identify both funding sources and project costs
11. Obtain national commitments to support development activities
    a. Financial contributions
    b. Assess national Jordanian capabilities for directly contributing to project development
    c. Identification of (potential) host country-specific activities and cooperative / collaborative activities
12. Develop and execute stakeholder engagement plans in potential host and user countries. Such engagement plans could be based on a set of core materials developed collaboratively, but then adjusted by each participant to meet the specific needs and conditions of its country (and particular communities within the country)
13. Establish business case and financial model, including:
    a. estimated RW/SNF volumes among participants and potential other future customers
    b. estimates for customer fees, reservation fees, and ownership stakes (depending on preferred model)
    c. estimated timing of SNF transports and disposal milestones, timeline and amount of funds for reservation fees payment (dependent on national storage and disposal requirements)

    d.

14. Finalize preferred host country. Having a viable candidate host country will make the project more credible, and it will move all further steps from theoretical to practical, as they will be tailored to the candidate host country
15. Address Legal / Regulatory framework in host country (including permitting issues at all levels)
    a. Integrate such matters into overall project schedule
    b. Assign lead responsibilities for each action
    c. Create alignment between project team and host country regulatory authority on design approach to MNR
    d. Create alignment between project team and host country regulatory authority (and any other relevant authorities) on logistics for importation of RW / SNF into host country
    e. Create alignment between project team and host country regulatory authority regarding allowed types of RW / SNF for the MNR, including permissible containerization / encapsulation options (and acceptance criteria)
16. Development of local incentive program
    a. Local incentive program will impact commercial factors
    b. Local incentive program will be an element of the host country-specific stakeholder engagement plan
    c. "Local" could be more than just the immediately surrounding community – it could also consider the state/province and the host country itself
17. Conduct of detailed feasibility study

    Having a preferred host country will enable a detailed feasibility study to be performed. Other elements of the PDP that follow below could form elements of the feasibility study.
18. Develop host country-specific stakeholder engagement plan (including local incentive program and Environmental and Social Management Plan (ESMP) elements; *see below*)

    The stakeholder engagement plan can be informed by a the "Lessons Learned" analysis of national programs.
19. Selection of Technical, Financial, and Legal Advisors
    a. Project development organization will need external advisors to support all activities
    b. While external support will probably be needed at earlier stages, bringing in a formal advisory team after a preferred host country has been identified would be timely
20. Develop ESMP for host country
    a. Application of Equator Principles,[41] etc.

[41] The Equator Principles (see https://equator-principles.com/) are a risk management framework, adopted by financial institutions, for determining, assessing, and managing environmental and social risk in development projects.risk assessment table

b. Alignment of international standards with local/national legal and regulatory requirements. Project should be designed to the higher standard, in order to support international financing strategies

21. Establish project participation structure
    a. Customer Agreement
    b. Ownership Agreement
    c. Timing of national approvals and commitments
22. Create project schedule and project cost. These are the Owner's estimates, which will then be updated after the EPC Contract has been signed
    a. Project schedule should be logic-based
    b. Project schedule should include critical path methodology
    c. Project schedule should have an accompanying Project Execution Plan (Owner's view), to include the means and methods for developing, constructing, and operating the Project, to include monthly cash flow (sources and uses, to include projected revenue during operations) for the project
23. Develop procurement strategy, including:
    a. Key buying factors
    b. Localization
    c. Contracting approach
24. Determine fiscal and other support from host country (tax, etc.)
    a. Tax incentives, etc. would enhance the project's economics
    b. Consideration of country-specific project execution risk factors should be considered in greater detail (than at the preliminary stage above), identifying possible adjustments that could be made to enhance the likelihood of project success
25. Development of financing structure / financing plan, including:
    a. preparation of Project Information Memorandum
    b. contribution of existing national reserved funds to support project activities (amount, timing, etc.)
    c. creation of a Trust / Management Account Structure (including oversight / control of the same)
    d. conduct Market Sounding
    e. establish preferred debt/equity structure
    f. consider existing national funds from electricity surcharges, and how those funds can be best utilized to support the financing plan and the project's overall economics
    g. Financial Close, meaning not only that the financing documents have been signed, but also that the prior conditions for the availability of financing have been fulfilled, should align with award of EPC Contract
26. Development of Insurance Program
    a. preliminary engagement of insurers
    b. consideration of national, regional, international insurance pools

c. pricing of project-specific insurances

NOTE: from here through to item 31, the PDP steps for an MNR are essentially the same as would be carried out for a national GDR

27. Performance of detailed site and subsurface characterization
    a. Preliminary assessment would have already been done in order to establish preferred host country; further analysis would need to be done for constructability
28. Development of final Design
    a. Design would be influenced by "lessons learned" analysis
    b. Completion of this activity would be represented by:
        i. Approval of ownership group and/or customers (to include their regulatory authorities), such that critical mass of participants remains
        ii. Approval of host country regulatory authority
29. Award of EPC Contract
    a. EPC Contract approach should be discussed by participants in advance of procurement activity, addressing matters such as:
        i. Risk allocation
        ii. Pricing
        iii. Contract Form
        iv. Key Terms
    b. EPC should include project execution plan with funding drawdown schedule
    c. Project execution plan should include means and methods for constructing the project, to include labor sourcing, logistics, and supply chain
    d. The EPC Contract should be aligned with Financial Close
30. Development of Operating Organization
    a. Financing, roles and responsibilities, human resources, education and training, knowledge management, etc.
    b. Operating Agreement terms and conditions
    c. Licensing
    d. O&M Budget
    e. Best practices relating to security, safety, and safeguards
31. Establishment of "Major Milestones", "Key Performance Indicators" (KPI) and "Exit Ramps"
    a. The PDP will need to consider Major Milestones and KPIs as part of the overall development schedule
    b. Major Milestones could involve key decisions
    c. Key decisions could form the basis of further funding commitments
    d. Key decisions and/or the achievement of Major Milestones monitored through KPIs could trigger Exit Ramps
    e. Exit Ramps would need to be clearly written into any development / project agreements that otherwise bind the project participants

f. The departure of a project participant will change the allocation of financial responsibilities among the project participants, which will also need to be clearly articulated

A3.5.2 Fall-Back Positions if MNR is Delayed or Cancelled

At the point when Jordan must fully commit to the MNR path of the dual track approach, it will need to consider ways to protect its interests if problems arise with the MNR project as it progresses. This commitment point would be the classic “Final Investment Decision”, when all interested participants must make binding legal commitments to proceed with the MNR. Such a binding legal commitment would be in the form of a contractual obligation (i.e., Investment Agreement, Participation Agreement, etc.), and Jordan would expect to see suitable provisions within the relevant agreement that protect its national interests.

Suitable protections would include:

1. If funds are committed to the MNR project, and the project is cancelled, or Jordan exercises a “right of withdrawal” in accordance with the terms of the agreement, then any unused funds from Jordan would need to be returned.
2. A “right of withdrawal” would be based on the MNR project failing to make suitable progress per the terms of the agreement. Through the identification of major milestones for project progress, links to both exit ramps and funding contribution requirements could be established. It would be expected that any failure to achieve a major milestone would lead to a cure period before any withdrawal action could be taken.
3. Certain participation rights would be included, such as access to project information, receipt of monthly reports, site access for project visits/inspections, and approval of “Major Project Decisions” (which would be negotiated by the parties prior to execution of the MNR project agreement). Such rights would be structured around the idea of proactive participation, information sharing, and oversight, with the purpose of making sure that a participant is not surprised by negative project developments. Recognizing that the participating country will retain responsibility for its spent fuel / nuclear waste prior to transfer to the fully functional facility, the participant will need to ensure that the MNR project is making suitable progress; otherwise, the participant will need to revert to a domestic solution. Such a reversion to a domestic option would be a significant disruptive event, both for the MNR project and for the participant. Consequently, monitoring and structured engagement will prepare all parties for MNR project challenges, remediation measures, and final decisions, such that outcomes will be anticipated well before they occur.
4. Additional rights would also be triggered in the event that the project is experiencing difficulties. If major milestones are missed, or if the costs are exceeding agreed expenditures, then a participating country should be able to exercise rights, such as increased project oversight and reporting requirements, requests for (and approval of) recovery plans, and the right to appoint new key personnel (e.g., project manager, construction manager, lead project engineer, site manager, etc.).
5. In addition, participants could take action against a defaulting / non-performing participant, in which case, voting rights and remedies will need to address collective action, to include removal of a participant, as a means of protecting the collective interests of the remaining participants.
6. Protection against cost overruns will be difficult to manage as a co-owner of the facility; however, as a participant, the expectation would be to have a price “locked in” before committing to be a participant. If a co-owner, protections would need to be managed

vis-à-vis third-party contractors; however, given the first-of-a-kind aspect of the MNR, it will be difficult to obtain a lump sum turnkey approach for construction of the MNR, in which case, the ownership group will need to manage the project proactively, with particular investment in pre-construction planning activities.

Any reversion to the national path of the dual track approach after making the initial choice to pursue the MNR path would be a major decision for the participating country. Thus, it is recommended that all prior work on a DGR be preserved such that the participant can resume the DGR. Thus, the DGR path of the dual track approach remains relevant until such time that the MNR is in operation.

A3.6 A Preliminary Framework for an MNR Risk Register

The tabulated risk register introduced in this Appendix is incomplete and intended only for illustrative purposes and is not intended to capture every issue. Similarly, the "Conclusions" column may not fully capture all aspects of a particular issue. Along with the SWOT and Multi-Attribute Decision Analysis (MADA) exercises recommended as next steps in the main report, eventual development of a risk register would be a useful way to explore the implications of possible involvement in an MNR project in more depth.

	ISSUE	DESCRIPTION	LIKELIHOOD	IMPACT	CONCLUSIONS
1	Host Country Commitment	• Inability to identify a host country at all • Inability to identify a host country in a suitable timeline	• Medium • Medium	• Very High • Very High	• Fatal to project if a host cannot be found. • Need for active management / engagement with interested parties • Favorable economic benefits to host country make it a reasonable presumption that a suitable host country will arise (eventually).
2	Cost	• Concern that cost becomes untenable after Jordan has given support to MNR concept	• Low	• High	• Given cost data on existing efforts (e.g., Finland), it is reasonable to presume that sufficient early-stage work could establish bounds within which a target price is viable.
3	Schedule Delay	• Project is not ready on time	• High	• Medium	• Impact depends on (i) continued viability of temporary surface storage in Jordan; and (ii) length of delay (esp. relative to cost impact).
4	Cost Overrun	• Project exceeds target cost	• High	• Medium	• It is reasonable to assume that the final price will exceed the target; the impact is assessed on the magnitude of the overrun. • With lessons learned from existing efforts (e.g., Finland), reasonable acceptable bands around a target cost could be established (subject to the level and quality of front end / preliminary engineering and detailed design that has been done prior to finalization of target cost.
5	Host Government Abandonment	• After Jordan has committed to project, Host Government cancels project	• Medium	• High	• Any number of factors could serve as the basis for Host Government to change its mind.

	ISSUE	DESCRIPTION	LIKELIHOOD	IMPACT	CONCLUSIONS
					• Strong contractual protections can be used to protect Jordan's interests. • Work done on dual track analyses prior to committing to MNR can be renewed.
6	Lack of Sufficient Participant Interest	• Critical mass of countries cannot be obtained	• Very low	• Low	• If a suitable host country is found, and proper structuring is done, it is reasonable to expect a high interest in participating countries. • Commitments can be monitored while still under a dual track approach so that impact is minimized.
7	Default of Participant	• Participant fails to meet its contractual obligations financially	• Low to Medium	• Medium	• Likelihood can be minimized depending on manner in which countries commit funds (possibly in advance) and how they source funds within their programs. • Impact is "Medium" as it depends on the size of the defaulting participant, when it defaults, and the contractual remedies established within the MNR contractual structure.
8	Withdraw of Participant	• Participant exits project after binding commitments are made	• Low to Medium	• Low	• Incentive structure should make this unlikely. • Contracting structure should create suitable protections. • Note, however, litigation risk reinforcement of contractual protections.
9	Nuclear Incident	• Nuclear release during transportation • Nuclear release at MNR during operation of facility	• Very low	• High	• Transportation has proven to be safe. • Containerization / Confinement of nuclear materials during transport is reliable. • FOAK operational risks should be resolved, given precedent projects (e.g., Finland, WIPP, etc.). • An incident could have public relations ramifications that could compromise project, even if effect is minimal / manageable. • Severe event at MNR site could terminate project.
10	Unacceptability of Fuel	• Mismatch of Spent Fuel with acceptance criteria of MNR	• Very low	• High	• Prior planning should make this a non-issue.

	ISSUE	DESCRIPTION	LIKELIHOOD	IMPACT	CONCLUSIONS
11	Lack of Financing	• Inability to obtain adequate financing to support the project	• Low to Medium	• Very high	• Fatal to project if it cannot be financed. • Achievable if project is structured to (i) capture economies of scale; and (ii) pool resources, especially existing reserves of funds from certain key participants. • Determining factors will include: (i) whether the project is "for profit" or "non-profit"; (ii) guarantees to be provided by host government and/or participants (as shareholders); (iii) strong likelihood of export credit finance, depending on how content is established; (iv) how early-stage work is funded; (v) level of financial support from host country.
12	Contractual Structure for Participation	• Participation structure does not fit Jordan's interests • Rights & Remedies are deemed inadequate by Jordan	• Low	• Medium/High	• At the extreme, an undesirable structure could force Jordan to opt out of the project; depending on the balance of issues, Jordan might be able to balance its various interests in a manner that still enables full participation. • Active participation at the formative stages can protect Jordan's interests. • Active project design modeling by Jordan to inform its participation in external MNR discussions can identify key issues for Jordan, well in advance of their emergence.
13	Instability in Host Country or Region	• Host Country becomes a security risk	• Low	• Medium	• Low likelihood if country is chosen based on a set of factors that includes stability/security. • Medium, based on timing of event and ability of Jordan to delay shipments until security situation is resolved.
14	Technical Problems in Design and/or Execution	• Project experiences technical challenges in development and construction period	• Low to Medium	• Medium	• Low if site selection work is done properly. • Low if design draws from prior experiences. • Medium likelihood if design has to incorporated scaled approaches to accommodate customer base / volume, and such scaling deviates substantially from reference designs. • Medium impact, depending on magnitude of challenge.

	ISSUE	DESCRIPTION	LIKELIHOOD	IMPACT	CONCLUSIONS
15	Technical Problems in Operation	• Project experiences operational difficulties	• Low	• Medium	• Low, given that actual operation of a storage facility should not be complicated, if properly designed. • Medium impact, depending on magnitude of issue.
16	Insurability	• Insurance market is not willing to support the project (or pricing is untenable)	• Medium	• High	• Medium risk, given perceived FOAK issues (but could be mitigated based on use of reference design, to the extent applicable). • High impact, as insurability (lack of) could make the project not viable.
17	Terrorist Act	• MNR facility could be targeted by terrorists • Fuel shipments could be targeted by terrorists	• Low • Low	• Medium • Medium	• Project plan should include adequate physical security measures. • Impact could be significant, depending on scale and impact of attack. • Nuclear shipments have not been targeted by terrorists to date.