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# Framework and Challenges for Initiating Multinational Cooperation for the Development of a Radioactive Waste Repository

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# FRAMEWORK AND CHALLENGES FOR INITIATING MULTINATIONAL COOPERATION FOR THE DEVELOPMENT OF A RADIOACTIVE WASTE REPOSITORY

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# FRAMEWORK AND CHALLENGES FOR INITIATING MULTINATIONAL COOPERATION FOR THE DEVELOPMENT OF A RADIOACTIVE WASTE REPOSITORY

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# FOREWORD

One of the IAEA's statutory objectives is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world." One way this objective is achieved is through the publication of a range of technical series. Two of these are the IAEA Nuclear Energy Series and the IAEA Safety Standards Series.

According to Article III.A.6 of the IAEA Statute, the safety standards establish "standards of safety for protection of health and minimization of danger to life and property". The safety standards include the Safety Fundamentals, Safety Requirements and Safety Guides. These standards are written primarily in a regulatory style, and are binding on the IAEA for its own programmes. The principal users are the regulatory bodies in Member States and other national authorities.

The IAEA Nuclear Energy Series comprises reports designed to encourage and assist R&D on, and application of, nuclear energy for peaceful uses. This includes practical examples to be used by owners and operators of utilities in Member States, implementing organizations, academia and government officials, among others. This information is presented in guides, reports on technology status and advances, and best practices for peaceful uses of nuclear energy based on inputs from international experts. The IAEA Nuclear Energy Series complements the IAEA Safety Standards Series.

It is generally accepted that the ultimate responsibility for ensuring the safety of spent fuel and radioactive waste rests with the government of the State in which it was generated. This does not mean that the fulfilment of national obligations through collaboration with other countries should be precluded. The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management states "that, in certain circumstances, safe and efficient management of spent fuel and radioactive waste might be fostered through agreements among Contracting Parties to use facilities in one of them for the benefit of the other Parties, particularly where waste originates from joint projects". This collaboration can extend through all steps of management of the back end of the fuel cycle and, in fact, cooperation between waste management organizations in different countries is well established, particularly in the area of research and development.

This publication addresses potential cooperation between countries for the disposal of spent fuel and radioactive waste and explores different aspects of this option, including its challenges and risks. It suggests and strongly encourages that Member States interested in multinational disposal have a coherent national disposal policy and strategy that is based upon national plans for disposal within their own territories. In addition, Member States may include involvement in a multinational repository project as part of their national strategy (the so-called dual track strategy).

The IAEA officers responsible for this publication are L. Nachmilner, J. Faltejsek and I. Mele of the Division of Nuclear Fuel Cycle and Waste Technology.

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# CONTENTS

# SUMMARY

The safe disposal of radioactive waste, and spent fuel when considered waste, continues to be an issue in all countries that use nuclear power for electricity generation and also for those in which radioactive materials are used for medical, research and industrial applications. The main concern is with long lived radioactive waste that requires special measures to ensure that it is isolated from people and the biosphere for the very long periods required for the decay of radioactivity to levels that do not present a significant hazard. It is generally accepted that the only feasible method by which long lived waste can be managed safely in the long term is to dispose of it in geological repositories.

Countries are encouraged to establish a national policy and a technical strategy, or strategies, for the management of their radioactive waste. The two concepts are linked; the policy establishes the principles for radioactive waste management and the strategy contains the approaches for the implementation of the policy. Being a partner in a collaborative repository development project does not remove the requirement that each country should have a national policy and strategy. Involvement in a multinational repository project should be seen as one of the options in a national policy and strategy.

This publication describes a phased approach and indicates the decision processes to be followed by partners in the multinational project, both within a national context and in the scope of the joint endeavour. It touches on a wide range of legal and institutional aspects, including the contractual obligations among partners; economic and financial arrangements; liabilities; nuclear security; regulatory and legislative aspects; waste transportation arrangements; and social matters. The uncertainties and risks involved in the implementation of a multinational repository are also addressed. The main intention is to provide the Member States with neutral, technically sound and balanced information on the multinational repository option.

A hypothetical reference scenario of a cooperative approach to a shared disposal facility is presented in this publication. This reference scenario selected for the purpose of this study is based on a partnership between countries in roughly similar situations and with similar problems located in the same geographical region (e.g. industrialized countries with small nuclear programmes or countries with small quantities of radioactive waste and in varying stages of development). These countries, referred to as the participating countries, agree to cooperate within a multinational framework for the mutual benefit of all the participants.

A process with five phases for the implementation of a multinational repository project is presented in this publication. Phase I covers the generic preliminary investigations necessary for evaluating the potential benefits and challenges of multinational projects. It finishes with recommendations from the working group assembled for the task to governments in the participating countries specifying how a formal multinational repository development organization (MN-RDO) might be established and operated.

Phase II includes all of the further assessments, actions and preparations to be undertaken by the interested countries individually and collectively before the MN-RDO can be formally established.

Phase III covers the initial activities of the MN-RDO. Once it is established, the MN-RDO must finalize and formalize its overall waste management strategy. This involves agreeing the organization structure, financing, technical disposal concepts, siting strategy and so on.

Phase IV comprises all the activities of the MN-RDO including the key milestone of agreeing a repository host country (and possibly location) and up to completion of the site selection and confirmation. Much technical work is involved — developing inventory databanks, assessing repository designs, building safety assessment capabilities and so on — but the greatest challenge will be to create and carry out a siting process based on achieving the consent of all relevant stakeholders. The phase ends with site confirmation and establishment of the appropriate implementing body, which is then domiciled in the volunteer host country.

Phase V, the implementation of the multinational project, is a multidecade phase that includes repository construction, operation, closure and post-closure monitoring. It will be very similar to the national repository implementation projects carried out in countries that have large nuclear power programmes and have opted for a national repository solution.

As a large scale, highly technical and also innovative investment project, which extends over several decades, the multinational project is politically and socially sensitive. For a successful outcome, it will be necessary to manage the associated risks in a professional manner. Risks to the project are examined in terms of the following threat categories: technical, economic, institutional and sociopolitical. Examples of possible disruptive events are

highlighted in each of the categories, and the expected impact on project progress and partnership arrangements is briefly noted. This is followed by a summary of relevant mitigating measures that can be applied. In practice, risks may fit into than one problem or threat category, in which case they are classified under whichever category will play the most decisive role in the outcome of the project.

# 1. INTRODUCTION

## 1.1. BACKGROUND

It is generally accepted that the ultimate responsibility for ensuring the safety of spent fuel and radioactive waste rests with the government of the State in which it was generated [1–5]. This does not mean that countries should be precluded from fulfilling their national obligations through collaboration with other countries. The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [1] states "that, in certain circumstances, safe and efficient management of spent fuel and radioactive waste might be fostered through agreements among Contracting Parties to use facilities in one of them for the benefit of the other Parties, particularly where waste originates from joint projects". This collaboration can extend through all steps of management of the back end of the fuel cycle and, in fact, cooperation between waste management organizations in different countries is well established, particularly in the area of research and development.

This publication addresses potential cooperation between countries for the disposal of radioactive waste, and spent fuel when considered waste. In the past decades, several IAEA studies related to the feasibility of establishing multinational repositories have been undertaken. For example, a publication issued in 1998 [6] concentrated on the technical, economic, institutional, political and social aspects of such a multinational project. A second study published in 2004 [7] examined the infrastructural requirements for multinational repositories and the possible scenarios of cooperation between participating countries, and a publication issued in 2011 [8] considered the viability of specific proposals that have been put forward for a multinational repository. In 2005, publications examined aspects of nuclear spent fuel storage [9] and multilateral approaches to the whole nuclear fuel cycle [10]. These studies are summarized in Appendix I. There have also been other international discussions on this subject [11−17], as briefly described in Appendix II.

The safe disposal of spent fuel and radioactive waste continues to be an issue in all countries that use nuclear power for electricity generation and also for those in which radioactive materials are used for medical, research and industrial applications. The main concern is with long lived radioactive waste which requires special measures to ensure that it is isolated from people and the biosphere for the very long periods required for decay of the radioactivity to levels that do not present a significant hazard. It is generally accepted that the only feasible method by which long lived waste can be managed safely in the long term is to dispose of it in geological repositories.

Progress is being made towards the development of geological repositories in most countries with significant nuclear programmes. However, at the time of writing, no repositories for the disposal of spent fuel and high level waste (HLW) were operational. The reasons for this are partly technical and partly societal.

Countries with relatively large nuclear power programmes usually have the resources and means to establish geological repositories for their own individual use, but countries with smaller programmes may find it difficult to implement complex and capital intensive repository projects.

It has been stressed in the discussions held on this subject to date [6–9] that it is not appropriate for a country to define involvement in a multinational repository as the sole strategy for disposing of its radioactive waste. The uncertainties and risks involved in the implementation of a multinational repository make this unacceptable as the only national strategy (see Section 7). Instead, countries should have a coherent national disposal policy and strategy that is based upon national plans for disposal within their own territories. In addition, they may include involvement in a multinational repository project as part of their national strategy (the so-called dual track strategy).

The advantages and disadvantages of including the option of multinational repositories within the national strategy will vary from country to country depending, among other things, on the scope of the domestic nuclear programme, national technological capabilities, national institutional framework, economic conditions, public acceptance of waste repositories and geographical location.

## 1.2. OBJECTIVE

The previously mentioned IAEA publications [6–9] set out the associated potential safety, security and economic benefits of multinational disposal. They are mainly aimed at experts involved in organizing or implementing radioactive waste management programmes. While the political, public and institutional aspects

of implementing a multinational disposal project are acknowledged in these publications, it was not within their scope to address these aspects in detail. These aspects are important and can represent the greatest challenges in implementing a multinational repository project.

This publication aims to build on previous work by providing information to politicians and decision makers on the decisions needed in relation to multinational repository projects.

## 1.3. SCOPE

This publication is concerned with radioactive waste that requires geological disposal. It discusses the partnership arrangements necessary for the development of a multinational repository for disposal of this waste. This publication focuses on the approaches based on the scenario for cooperation among countries in joint projects for the establishment of a shared geological repository, as presented in the IAEA publication on Developing Multinational Radioactive Waste Repositories: Infrastructural Framework and Scenarios of Cooperation [7].

This publication describes the phased approach that would be needed to develop a multinational repository, indicating the decision processes to be undertaken by partners in the multinational project, both within a national context and in the scope of the joint endeavour. It touches on a wide range of legal and institutional aspects, including the contractual obligations among partners; economic and financial arrangements; liabilities; nuclear security; regulatory and legislative aspects; waste transportation arrangements; and social matters. The uncertainties and risks involved in the implementation of a multinational repository are addressed in a separate section.

The discussion is thus particularly relevant for countries with small nuclear programmes and for countries planning to establish new nuclear programmes, as well as for countries without nuclear power plants but with long lived radioactive waste from medicine, industry and research.

As emphasized in the introductory text above, it is assumed that all countries involved in a multinational repository initiative have a coherent national disposal policy and strategy. This means that the multinational initiative would be treated initially as part of a dual track strategy including both national and multinational components.

## 1.4. STRUCTURE

Section 2 summarizes the important elements of IAEA guidance that are applicable to radioactive waste management programmes in general and which should be taken into account for shared disposal programmes. Section 3 discusses multinational cooperation efforts within the whole of the back end of the fuel cycle and describes potential cooperation scenarios. Section 4 sets out a specific reference scenario in which a number of countries agree to a partnership approach for the development of a shared geological repository. Section 5 addresses the development and implementation of a voluntary siting strategy. Section 6 describes the phased approach to establishing a multinational repository concluding with the implementation of the repository in a voluntary host country and at an identified site. Section 7 provides an overview of the main risks involved in a multinational undertaking and the proposed mitigation measures that can be applied to alleviate these risks. Section 8 forms the conclusion of the publication, which also contains four appendices.

# 2. NATIONAL POLICIES AND STRATEGIES FOR MANAGING RADIOACTIVE WASTE

## 2.1. POLICY AND STRATEGY

In 2009, the IAEA issued a publication [2] that provides guidance on establishing national radioactive waste management policies and strategies. Countries are encouraged to establish a national policy and a technical strategy, or strategies, for the management of their radioactive waste. The two planning concepts are linked; the policy establishes the principles for radioactive waste management and the strategy contains the approaches for the implementation of the policy. For this reason, they should be closely coordinated: policy is mainly the responsibility of the national government and may become codified in the national legislative system while strategy is usually established by the relevant waste owner or nuclear facility operator, or by the government.

Being a partner in a collaborative multinational repository development project does not remove the requirement that each country should have a national policy and strategy. Involvement in a multinational repository project should be seen as one option in a national policy and strategy.

## 2.2. POLICY ISSUES IMPORTANT FOR MULTINATIONAL COOPERATION

From a multinational perspective, the following issues are important when formulating a national policy and strategy for radioactive waste and spent fuel management: export/import of radioactive waste, spent fuel management, radioactive waste management, and public information and participation.

### 2.2.1. Export/import of radioactive waste

It may have been decided that national facilities for the storage and/or disposal of radioactive waste should not be used for waste from other countries; this decision may even be incorporated into national legislation, as is the case in a number of countries. Some countries also take the position that radioactive waste should not be exported. On the other hand, some countries are interested in exploring the possibilities for international solutions for the long term management of radioactive waste and allow the possibility of exporting and importing radioactive waste. Paragraph (xi) of the Preamble to the Joint Convention [1] recognizes the validity of such solutions, and the requirements for ensuring the safety of the relevant operations are specified in Articles 27 and 28.

The national policy may, thus:

— Leave the question fully open;
— Specify conditions applying to the import and/or export of radioactive waste;
— Declare an intention to store/dispose of radioactive waste on national territory;
— Indicate an intention to engage in international/regional solutions.

Table 1 summarizes the national legal and policy situation concerning waste import/export in a number of countries.

TABLE 1. NATIONAL POLICIES CONCERNING IMPORT AND EXPORT OF RADIOACTIVE WASTE[1]

| Country | Disposal policy for HLW/Spent fuel, attitude towards international repository | Import for disposal permitted? | Export permitted? |
|---|---|---|---|
| Australia | National | Yes (under certain conditions) | Yes (under certain conditions) |
| Austria | Return to USA (research reactor only) | No | Yes (under certain conditions) |
| Belgium | Dual track; 1st priority national | Yes (under certain conditions) | Yes (under certain conditions) |
| Croatia | No official policy | No | Left open |
| Czech Republic | Dual track; 1st priority national | No | Yes (under certain conditions) |
| Finland | National only | No | No |
| France | National only | No | Yes (under certain conditions) |
| Germany | National only | Yes (under certain conditions) | Yes (under certain conditions) |
| Hungary | Dual track; 1st priority national | No | Yes |
| Italy | No official policy | No | Yes (for treatment) |
| Japan | National only | Yes (under certain conditions) | Yes (under certain conditions) |
| Latvia | Dual track | No | Yes (under certain conditions) |
| Lithuania | Dual track | No | Yes (under certain conditions) |
| Netherlands | Dual track | Left open | Left open |
| Romania | No official policy | No | Yes (under certain conditions) |
| Russian Federation | National only | Yes (under certain conditions) | Yes (under certain conditions) |
| Slovakia | Dual track; 1st priority national | No | Yes (under certain conditions) |
| Slovenia | Dual track | Yes (under certain conditions) | Yes (under certain conditions) |
| Spain | No official policy | Yes (under certain conditions) | Yes (under certain conditions) |
| Sweden | National only | Yes (small quantities, under certain conditions) | Yes (under certain conditions) |
| Switzerland | Dual track; 1st priority national | Yes (under certain conditions) | Yes (under certain conditions) |
| United Arab Emirates | Dual track | No | Yes (under certain conditions) |
| United Kingdom | National only | Yes (under certain conditions) | Yes (under certain conditions) |
| United States of America | National only | Yes (under certain conditions) | Yes (under certain conditions) |

[1] An example of requirement for national policy is defined in article 4 of the European Union Council Directive 2011/70/Euratom establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste [11].

### 2.2.2. Spent fuel management

The approach to the management of spent fuel must be in keeping with the provisions of the Joint Convention [1]. There are three possibilities: the national policy may consider spent fuel as a resource with the spent fuel being utilized through reprocessing (nationally or internationally) and the resulting HLW being disposed of afterwards; the national policy may be to regard the spent fuel as a waste to be disposed of directly; or the national policy may require that spent fuel is returned to the supplier. This last option is directly affected by the import/export policy of both the user and supplier countries.

### 2.2.3. Radioactive waste management

Disused sealed radioactive sources are only one component of the national radioactive waste inventory but they are particularly important for countries with little other radioactive waste to manage. Management options to be addressed at the policy level include the return of the disused sealed radioactive sources to the supplier, management of the sources on national territory and international management solutions [1, 2].

### 2.2.4. Public information and participation

Public information and participation is a crucial part of any radioactive waste management policy. Owing to the political sensitivity of multinational repositories, national policy should be particularly clear on this issue. The policy should specify the procedures applying to the public participation and consultation process. Proposed plans for radioactive waste management should be submitted for comment, and concerned parties and members of the public should be invited to provide input to the decision making process.

# 3. SCENARIOS FOR MULTINATIONAL COOPERATION IN RADIOACTIVE WASTE MANAGEMENT

## 3.1. MULTINATIONAL COOPERATION

There is significant multinational cooperation in several areas at the back end of the nuclear fuel cycle. National radioactive waste management organizations cooperate within various frameworks as indicated in the examples given in Appendix I. However, there has been only limited cooperation on implementing radioactive waste disposal [18].

When examining the possibilities for multinational cooperation in the context of radioactive waste disposal, it is useful to define possible scenarios in which such cooperation could develop. It is possible that a potential host country (or countries) could be identified at an early stage of repository development and implementation. Alternatively, countries may initially come together to discuss the advantages and drawbacks of a shared repository, without defining, at the outset, one or more potential host countries. This is similar to the ‘compact’ system under which different groupings of states in the United States of America have sought to establish a common low level radioactive waste repository.[2]

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[2] In the USA, States may join together to build regional facilities by forming organizations called compacts. The Low-Level Radioactive Waste Policy Act defines a compact as a legal agreement between two or more states to share in the disposal of low level radioactive waste. At the time of writing, there were ten compacts, but only four active, licensed low level radioactive waste disposal facilities; disposal at these facilities was restricted by waste class and compact membership. The four active, licensed repositories were US Ecology, located in Richland, Washington (accepts the 11 member states of the Northwest and Rocky Mountain Compacts), EnergySolutions Clive Operations, located in Clive, Utah (accepts waste from all regions of the USA), EnergySolutions Barnwell Operations, located in Barnwell, South Carolina (accepts waste only from the 3 Member States of the Atlantic Compact) and Waste Control Specialists, located in Andrews, Texas.

### 3.2. REPOSITORY SHARING SCENARIOS

In an IAEA publication [7], different scenarios for implementing multinational repositories were postulated. Three major possibilities were identified: 'add-on' (a large programme accepts waste from smaller ones), a 'supranational concept' in which a facility with truly international management and control is implemented, and 'partnering scenarios' in which countries collaborate in a multinational repository. The reference scenario developed for this publication is based on a partnering approach. Other approaches towards the development of shared repositories have been described in Refs [12, 13].

# 4. REFERENCE SCENARIO

### 4.1. PARTICIPATING COUNTRIES

The reference scenario selected for the purpose of this study is based on a partnership between countries in roughly similar situations and with similar problems located in the same geographical region (e.g. industrialized countries with small nuclear programmes or countries with small quantities of radioactive waste and in varying stages of development). These countries, referred to as the participating countries, agree to cooperate within a multinational framework for the mutual benefit of all participants. This scenario corresponds to a large extent, although not in all respects, to the IAEA cooperation scenario described in Ref. [7].

### 4.2. THE CONDITIONS FOR PARTNERSHIP DEVELOPMENT

The partnership arrangement within the reference scenario for the multinational venture is as follows:

— The participating countries are classified in three main categories: the host[3], partner[4] and transit[5] countries. (This grouping may not be possible at the outset of the venture, for example before the host country has been identified.) Other countries not directly involved in any of these ways can also influence progress with a collaborative initiative (e.g. neighbouring countries or countries with purely national disposal programmes that can support or oppose the multinational concept in a number of ways).
— The host, partner and transit countries will all have an established national policy and strategy for radioactive waste management; the multinational initiative is thus part of a dual track strategy. (It is noted, however, that it may be difficult to ensure these conditions are met in countries that are not partners, i.e. transit countries.)
— There will be a single host country, with several partner countries in various stages of nuclear power development and others without nuclear power plants.
— A host country is identified that can provide a suitable site for a safe repository and that, after weighing the benefits and drawbacks of implementing a shared facility, decides to volunteer its services as a host.
— The host country need not be identified at the outset of the project, as this decision may be taken later in the project, i.e. after completion of the site evaluation and selection process. Mutual agreement on which country should be the host is a decisive step, not only for the country concerned but also for the partner countries. Clearly, early declarations of willingness to consider hosting, or indeed an early agreement on the host country, would simplify many of the project steps, such as the siting exercise.

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[3] Host country: a country in which a shared repository is located that accepts radioactive wastes from one or more partner countries.

[4] Partner country: a country that takes part in the joint project on implementing a shared (multinational) facility; party in the partnership agreement on shared (multinational) repository. The terms 'customer country' or 'client country' are also used.

[5] Transit country: a country that is not directly a partner country in the project but can also influence the progress with the operation of a shared facility since the radioactive materials in transit will pass through its territory. The term 'third party country' is sometimes also used.

— Participating countries (whether host or partner) are free to withdraw from the joint endeavour at any time before the definitive siting decision has been made.
— All participating countries have the adequate national technical capacity and financial resources to participate in the joint endeavour or, at a minimum, to act as an 'intelligent customer' of the repository implementing organization.

## 4.3. PARTICIPATING COUNTRY POLICY AND STRATEGY

It is important that participation in a multinational initiative should not, for any country, serve as an alternative to having a national policy and strategy aimed at ensuring safe management of radioactive waste. Countries participating in a multinational initiative should follow a dual track approach in which the options of a purely national approach and multinational sharing are both kept open. This requires that countries develop an appropriate level of technical expertise and provide the necessary financial resources to maintain that expertise. Cooperation between countries participating in a multinational initiative can reduce the extent of the national resources deployed, but does not remove the need for them.

The viability of a multinational approach can be questioned until such time as a volunteer host country and a disposal site within it have been agreed. Accordingly, participating countries should maintain an independent national strategy for disposal until the radioactive waste is disposed of in the multinational facility.

## 4.4. PROJECT PHASES AND TIMEFRAME

When a group of potential participating countries has been identified and the countries concerned have indicated their willingness to take part in preliminary discussions concerning cooperative action towards establishing a multinational disposal project, a series of procedural steps or phases should be followed. These are briefly summarized below and further elaborated in Section 6.

In the given reference scenario, *Phase I* covers the generic preliminary investigations necessary for evaluating the potential benefits and challenges of multinational projects; these investigations might be carried out by an ad hoc working group from different countries. They will result in a knowledge base that should allow countries to decide in principle whether they wish to examine the multinational option in depth. Phase I finishes with recommendations from the working group to governments in the participating countries specifying how a formal MN-RDO might be established and operated.

*Phase II* includes all of the further assessments, actions and preparations to be undertaken by the interested countries, individually and collectively, before the MN-RDO can be formally established. Some of the actions needed include those taken by individual countries to decide upon their own readiness to engage in a multinational initiative; other activities involve initial interactions between potential partner countries in the framework of the ad hoc working group. This phase ends when a sufficient number of countries agree in principle to establish a formal joint MN-RDO domiciled in one (or more) of the member countries (but as yet with no prejudice concerning repository siting).

*Phase III* covers the initial activities of the MN-RDO. Once it is established, the MN-RDO must finalize and formalize its overall waste management strategy. This involves agreeing the organization's structure, financing, technical disposal concepts, siting strategy and so on.

*Phase IV* includes all the activities of the MN-RDO up to the key milestone of agreeing a repository host country (and possibly location) and until the completion of site selection and confirmation. Much technical work is involved — developing inventory databanks, assessing repository designs, building safety assessment capabilities and so on — but the greatest challenge will be to create and carry out a siting process based on obtaining the consent of all relevant stakeholders. The phase ends with site confirmation and establishment of the appropriate implementing body, which will then be domiciled in the volunteer host country.

*Phase V,* the implementation of the multinational project, is a multidecade phase that includes repository construction, operation, closure and post-closure monitoring. It will be very similar to the national repository implementation projects carried out in countries that have large nuclear power programmes and have opted for a national repository solution.

The participating countries must agree on the overall timeframe for the implementation of the multinational project. The timeframe indicated below is based on the phased approach as defined above, and merely serves as an indication of what an optimistic timescale may be.

— Phase I: From preliminary investigations to a working group recommendation to proceed towards a MN-RDO: 1–5 years;
— Phase II: Preparing for and initiating the MN-RDO: 1–4 years (political decisions needed);
— Phase III: Finalizing the strategy and roadmap of the MN-RDO and the subsequent multinational project implementing organization: 2–4 years (agreement of all participating countries needed);
— Phase IV: Operation of the implementing organization up to site selection: 10 years;
— Phase V: Implementation (5–10 years), operation (30–60 years), closure (5 years) and monitoring of the repository.

## 4.5. TECHNICAL ASPECTS OF THE REPOSITORY

For the reference scenario, it is assumed that the type of waste to be disposed of in the shared multinational geological repository is confined to long lived waste, originating from:

— The nuclear fuel cycle and/or nuclear power facilities: spent fuel, HLW, long lived low level waste (LLW) and long lived intermediate level waste (ILW);
— Outside the nuclear industry: long lived LLW and long lived ILW from nuclear technology applications in medicine, industry or research.

In practice, it is conceivable that the inventory could be expanded to include other low level waste types or indeed that a similar process could be initiated to implement a repository specifically for such waste.

The main safety and technical requirements, capabilities and activities needed for implementation of the shared geological repository are essentially the same as for a national repository. Countries participating in the multinational venture would be expected to transport their radioactive waste to the joint repository facility established at an agreed and approved repository site within the host country. The waste delivered to the repository would have to comply with the waste acceptance criteria established by the host country.

The multinational repository would typically comprise the following technical and related aspects:

— An agreed and approved repository site within the host country;
— A repository design and technical specifications based on the capacity needed for shared waste disposal;
— Definition of the required research and development activities, possibly involving an underground research laboratory (URL);
— A safety case with a supporting safety assessment which indicates a satisfactory future repository performance and compliance with safety requirements;
— Appropriate repository equipment (including containers, backfill, etc.);
— Repository construction capability — involving deep underground mining activities;
— Arrangements for repository commissioning and operation;
— Waste transportation systems facilitating waste transfer to the repository site;
— Institutional requirements relating to licensing, safety, safeguards and physical security precautions;
— Arrangements for final repository closure at the end of its life, followed by post-closure institutional control.

For optimized operation of the facility it would also be advantageous to have:

— Sufficient interim or buffer storage at the site;
— Waste conditioning and/or encapsulation facilities for the preparation of the waste packages, preferably situated on the repository site.

## 4.6. ECONOMIC VIABILITY

The participating countries should be convinced that the joint repository project is an economically viable undertaking. For this, the multinational repository capital and operating costs must be estimated at the commencement of the venture and the required funding mechanisms agreed. This requires all participating countries to agree on the potential benefits and costs that may arise from the multinational venture. Important economic aspects to be considered include:

— Setting the budget for the development phases and allocating the contributions of different participating countries;
— Establishing the direct and indirect benefits to be offered to the voluntary host country and community;
— Determining whether the implementer will offer disposal at cost price or at a profit;
— Establishing the costing/pricing algorithm to be used for setting waste specific disposal costs;
— Agreeing on whether the repository will be opened at later dates to a wider range of countries, and, if so, the financial conditions under these circumstances;
— Establishing the financial liabilities to be borne by participating countries in the case of malfunctions or accidents during the construction, operation and post-closure phases of the repository.

It is interesting to note that, although these are not easy matters to resolve, there are precedents for such negotiated discussions. In countries where legally separate individual power companies collaborate to establish a joint national disposal facility, an analogous set of issues have arisen. Examples of such countries are Finland, Sweden and Switzerland. The costs of the development phases listed above vary considerably.

*Phase I* consists of relatively low cost feasibility studies performed by small expert groups. The SAPIERR (Support Action: Pilot Initiative for European Regional Repositories) [12] and ERDO-WG (European Repository Development Organisation Working Group) [13] studies had budgets of the order of €100 000 to €300 000 per year.

*Phase II* costs will depend on what measures involving techno-economic and legal teams are taken by each country to arrive at a formal decision on participation; costs may be expected to be similar to those of Phase I.

*Phase III* costs are higher because a permanent organization with its own infrastructure has to be established. However, the MN-RDO can be of a modest size in its early stages; experience in national waste management programmes has indicated that a staff of 10–20 persons can suffice.

*Phase IV* costs are higher than those of the earlier phases, mainly because of the siting process. Modest national disposal programmes such as those of Finland, Sweden or Switzerland have expended tens of millions of Euro on this phase. Some large national programmes such as those of Germany or the USA have cost billions of Euro.

*Phase V*, the long implementation phase, is the most expensive. Life cycle costs for geological repositories start at billions of Euro. The possibility of sharing such costs with partner countries is one of the strongest incentives for small and embarking nuclear power nations to engage in multinational initiatives.

## 4.7. INSTITUTIONAL IMPLICATIONS

The participating countries should agree on institutional rights, responsibilities and obligations applying to the host, partner and transit countries, as well as to non-involved countries. These aspects should be incorporated into the legislative and regulatory framework of the respective participating countries and typically include the following:

— The host country should have a well developed institutional system capable of accommodating the licensing, safety, safeguards and physical security requirements.
— The partner countries should have institutional systems that are similar to those of the host country.
— Intergovernmental agreements will be required between countries if radioactive waste is to be transferred for disposal.
— Transit countries will require appropriate transport and cross-boundary institutional systems.

### 4.8. CONTRACTUAL IMPLICATIONS

The participating countries should agree on the contractual terms of the multinational undertaking covering the associated legal and project implementation issues. Provision is necessary, inter alia, for mitigation of project contingencies that could potentially jeopardize the entire project. One example of such a contingency is the withdrawal of participating countries from the joint venture at a future stage. These and other risks are discussed in Section 7.

Technical contractual arrangements may also be needed to ensure that the jointly owned repository can be operated in an efficient and cost effective manner. For example, it may be necessary to ensure that waste for disposal flows to the repository in an optimized manner. If participating countries have ample national storage capacities, they may need an incentive to encourage them to transfer waste from existing storage facilities to the repository, since the cost of waste transport can be high.

The participating countries should agree at the outset of the project on the maximum repository disposal capacity. If deemed necessary, such an agreement could make provision for the future expansion of the repository capacity under certain conditions.

### 4.9. LEGAL IMPLICATIONS

The legal implications of involvement in a multinational repository cover a wide range of topics. The most prominent of these are concerned with the transfer of ownership of the waste to the host country, the nuclear liabilities regime involved, waste transportation, commitment to the completion of the project and possible damage in the event of non-performance. The particular issue of transfer of ownership has been debated intensively and was considered in the SAPIERR project [12].

Even in national disposal programmes, there are complex legal issues connected with ownership of radioactive waste from the time of production to disposal. The producer of the waste is the initial owner, but other arrangements must be made as the material moves towards disposal. These differ from country to country. In some cases, the situation is clear, at least in principle. For example, in the USA, it is foreseen that the Federal Government will take title on spent fuel from utilities, and this includes all future responsibilities. This can work in cases where the government is also the repository implementer. The situation is more complex when the implementer is a third party, for example, a dedicated waste management organization outside the government. The possibilities then are that the original waste owners retain joint responsibility for future events or that a private body takes over the waste and also the responsibilities.

Ownership issues can be complex during the operational period of the repository; they become more complex in the post-closure period. The government of the host country must be involved because, in the long term, responsibility and ownership will finally lie with the host country. In a multinational project, the countries that export waste to a shared repository may transfer ownership at the outset, or may retain ownership for some time afterwards. The arguments most commonly made for retaining ownership are that liabilities for any unforeseen remediation activities are then also shared. If there is an emphasis on reprocessing spent fuel, however, the material in the repository may ultimately be seen as a valuable asset whose ownership must be defined. The issues of transfer of title and of long term responsibilities are likely to become the subject of supranational arrangements governed by intergovernmental treaties and agreements.

## 5. REPOSITORY SITING APPROACH

### 5.1. A STAGED SITING STRATEGY

In this section, an outline is given of how a group of countries coming together to seek a common solution to the geological disposal of their radioactive waste could work together to identify a repository site that is demonstrably safe and acceptable to the host nation and community. It describes a staged approach to the initial

identification of potentially suitable sites and outlines the activities that would take place at each stage up to the point of approving a site and repository design for disposal operations [19].

Step by step development of disposal facilities is required by IAEA Specific Safety Requirements SSR-5 [3]. This approach provides the opportunity to ensure the quality of the technical program and the associated decision making. The principles of such an approach to decision making have been described in overview documents produced by the National Research Council of the United States National Academies [20] and the OECD Nuclear Energy Agency [21].

For a multinational project, the suggested approach is one that can run in parallel with national siting efforts without prejudicing the outcome of either. A key aspect of the process described here is that it allows a progressive approach to identifying both host countries and host sites. The approach specifically avoids requiring partners in a shared multinational project to commit themselves at the outset to being a potential host country for a repository, or even to agree on a common optimized development timescale. For technical, programmatic, financial or political reasons, several stages of agreement are likely to be required before a host emerges. Each stage will be informed by progressively clearer, project specific and quantitative information (for example, on costs, benefits and impacts). As this process progresses, the improved information and the stepwise growth in project commitments should provide partners with increasing confidence in the eventual solution.

The greatest challenge is in achieving public and political acceptance in the countries where such repositories would be hosted. The siting of multinational disposal facilities may be seen as difficult to achieve, but it is not different in principle to the national problems faced internally within any country that wishes to identify a region and then a site for a national repository — and it can be addressed in the same way as it has been in successful national programmes. One of the significant advances of the last few years has been the development of a possible approach to siting a shared, regional multinational repository, based upon the volunteer siting methodology, which has already worked in two or three countries. The approach advocated is a volunteer model incorporating stakeholder involvement at all stages. It is technically guided only to the extent that clearly unsuitable regions are excluded at the start.

## 5.2. GOALS AND GUIDING PRINCIPLES

The overall goals of the multinational siting programme are to enable the implementing body to:

- Deliver a site or sites that are technically, politically and societally acceptable for a geological repository for all relevant long lived radioactive waste produced in the partner countries;
- Show that the selected site(s) meet all nationally and internationally accepted standards with respect to operational and long term safety and environmental impacts;
- Pursue a staged and progressive approach to identifying both host communities (sites) and host countries at an appropriate time in the project schedule, while avoiding premature external pressures to identify hosts at the outset;
- Work in harmony with parallel national siting programmes (dual track approach);
- Maintain flexibility and responsiveness in its operations, while presenting its work in a clear, transparent and auditable fashion.

An important question concerns how existing national siting programmes can be incorporated into this model. Partner countries that already have developed national siting programmes will be able to pool their knowledge, but they will also have to decide how to deal with sites and communities that are already being considered as possible national repository locations: will these sites be in the pool of potentially interested communities? For some countries, this will be an especially sensitive issue to resolve and will need consultation with the potential host communities already identified.

The following guiding principles can help in establishing the strategy. The siting approach should:

— Be based on a transparent selection process associated with agreed and well defined siting factors that identify clearly unsuitable areas (using exclusion factors), required (necessary) characteristics and preferred (favourable) properties of suitable sites;
— Seek volunteer host countries and communities from within the wide regions that are not already excluded for obvious reasons (e.g. unsuitable geology, dense population) and evaluate them on their merits;
— Take into full consideration the political and cultural challenges associated with its multinational nature;
— Identify relevant stakeholders;[6]
— Publish in advance information on any work starting and allow a period for consultation with key national and international stakeholders during a period when the overall legitimacy of the siting programme is being established;
— Be structured in clear steps with clear decision points and well defined responsibilities for all stakeholders involved at these points;
— Be flexible enough to adapt to changing requirements over the course of the project and the findings of each stage — it should be amenable to adjustment to accommodate stakeholder requirements at key stages;
— Provide up to date information to the public and stakeholders at each stage, with mechanisms and decision points for public feedback defined throughout the duration of the programme;
— Aim at finding safe sites that are the most suitable, taking all siting factors into account, rather than looking for the 'safest' site (as this can never be demonstrated);
— Compare sites transparently, using the siting factors and the selection process referred to above if there is more than one potential site;
— Involve the regulatory bodies of potential host countries and all partner countries from the outset of the project, to facilitate their work and make the licensing steps more transparent and efficient;
— Achieve a solution on the required timescales at reasonable cost and with reasonable use of resources.

### 5.3. A VOLUNTEERING APPROACH

A very important challenge is to develop a suitable process for ensuring that all stakeholders are involved in appropriate ways, especially national governments and local communities. Experience suggests that an entirely prescriptive approach (where technical choices are made by experts and then attempts are made to convince specific communities) is unlikely to succeed. Rather, an approach that involves some degree of volunteering on the part of interested countries and communities is to be preferred; this approach has met with success in some countries. In the volunteer model, the implementer does not seek sites, but waits for volunteers to propose potential sites whose suitability can then be objectively assessed.

A volunteer model that incorporates stakeholder involvement at all stages and is technically guided at the outset (insofar as clearly unsuitable regions are excluded at the start) is suggested as an optimum approach. This approach incorporates the flexibility to evaluate objectively any proposals that might emerge from volunteer communities, regions or countries, from the start of the programme.

An important aspect of this approach is the initial assumption that any location that is not obviously unsuitable on the basis of existing knowledge is worth considering on its merits as a possible repository site. This approach is based on the knowledge that many different geological environments can provide acceptable isolation and containment and that different repository concepts have been designed to take advantage of the range of conditions. Consequently, a volunteer location (in a non-excluded area) might well be rejected after only limited investigations if these indicate that it would be too difficult to make a reliable safety case or too costly to adapt designs to site

[6] The relevant stakeholders should be defined by the partner countries in the multinational project. It is expected that the initial group would include government departments, national regulatory agencies and scientific and strategic planning groups that advise governments, waste owners and national implementing organizations, national organizations representing local government, and the IAEA (plus the European Commission in the case of a European Union regional repository). Later, once specific locations emerge, the representatives of the communities expressing interest and their advisers will become the key stakeholders.

conditions. The essential element, however, is to maintain flexibility and not to exclude interested communities if there is a realistic likelihood that the site they are offering could prove suitable.

An important topic for discussion between partner countries in the MN-RDO is the approach to be used to solicit volunteers. This discussion must consider the national geographical levels at which volunteers are sought (community, county or district, region, country) and the roles and responsibilities of actors involved at each level. The latter point raises a list of sensitive questions, including:

— Must volunteering countries already have identified potential host communities?
— Does the government of a country have to actively volunteer or, more passively, simply agree not to block any local volunteers?
— Can local communities volunteer before national agreements are reached?
— At which of the above levels is consent to volunteer required?
— How does one define sufficient acceptance at each of the levels?
— Who has veto or withdrawal rights and at which project stages can these be exercised?
— Who negotiates the levels and the distribution of benefits for volunteers?

It is to be expected that the answers to these questions will differ between partner countries.

### 5.4. EXPECTED TIMESCALE FOR THE SITING PROGRAMME

The time expected to be taken for the overall siting programme (i.e. up to the point of commencement of repository operation) is likely to be between 15 and 20 years. This is based on experience from successful national programmes such as those in Finland and Sweden.

The actual time required will be affected by factors whose impact it is difficult to judge. An optimistic minimum schedule would allow around 5 years to establish the organizational infrastructure and agreements and to carry out the initial site identifications, a further 5 years to carry out detailed site investigations for the surface and another 5 years to construct access works, carry out further confirmatory underground investigations and submit a licence application to begin operations.

The time required for consultation and decision making is likely to be a constraint on progress in any siting project. Experience has shown that, even in national programmes, this time is difficult to predict, and that these processes can introduce uncertainties about the outcome at key decision points. In the multinational case, making contact with all relevant stakeholders in participant countries is obviously more challenging than in the national case, and consideration may need to be given to a staged approach, where stakeholders are brought into the process at the most appropriate time. For example, it may not be practicable or appropriate to try to engage with all municipalities in a country at the time of the first high level decision by a government. However, it is essential to communicate openly with the public to inform them of progress in the project and to solicit feedback on interim decisions. This can help minimize the time needed for societal debate and political verdicts on later choices and decisions.

## 6. A STAGED APPROACH TO MULTINATIONAL REPOSITORY IMPLEMENTATION

### 6.1. PHASE I — PRELIMINARY INVESTIGATIONS

In Phase I, the participating countries agree to carry out a joint feasibility study for a potential shared geological repository. They form an ad hoc working group of experts to perform studies on the implications of the technical, economic, institutional, legal, political and social aspects of the project, as well as on the potential benefits and challenges involved. This is effectively what took place in a European context in the SAPIERR studies

mentioned above [12]. The outcome of the feasibility study may be the proposal of a conceptual multinational implementation strategy. It is also conceivable that additional, more formalized, steps would be needed. In the European case, the ad hoc study teams that produced the SAPIERR reports were succeeded by a formal working group (the ERDO-WG described in Ref. [13]), the members of which were official delegates of those countries that had agreed to study the concept in more depth.

Already at the Phase I stage, the collaborating countries can benefit from participation in a multinational body. Participation in the multinational group can help to assist and ease progress in achieving this requirement for countries with limited resources.

Eventually, the ad hoc working group (or a more formal joint body) must reach consensus on a set of recommendations for the establishment of an official MN-RDO that they can submit to their national governments.

## 6.2. PHASE II — PREPARING FOR INITIATING THE MN-RDO

Following a positive recommendation from the working group to the respective governments of the participating countries, the multinational initiative can enter Phase II of the process. In this phase, participating countries, first at national level and then as a group, perform all further assessments and negotiations that have to be completed before they can formally sign up to be partners in a MN-RDO. It is suggested that this phase be accomplished in two successive steps: the first is at the national level within the respective participating countries, and the second at the multinational level in advance of the launching of the multinational project.

### 6.2.1. National activities relevant to multinational initiatives (step 1)

When the recommendations are submitted to the respective governments of the participating countries, the existing relevant governmental organizations within these countries should determine the administrative procedures that have to be followed. Each participating country is expected to have a national policy and strategy for spent fuel and radioactive waste management; these are to be used as the basis for evaluating the multinational proposal. The outcome of this process is a policy decision at governmental level within each of the participating countries to consider the multinational approach as one of its strategic options. A number of steps may be necessary as part of the decision making process within the respective countries.

A likely initial step is the establishment of a national team to coordinate the preparatory work needed for a multinational project. If a national waste management organization (WMO) already exists in the country, then the most efficient approach may be to integrate into the national team the national representative in the multinational working group together with WMO staff and other legal, financial and political experts as deemed necessary.

The national team should consider:

— Nuclear energy planning;
— Waste arising (both nuclear power plant (NPP) and non-NPP waste);
— Technical infrastructure (including non-nuclear);
— National disposal strategy (the implementation plan);
— Human and financial resources available nationally.

It may be necessary to revise the current national policy and strategy for radioactive waste management in order to align them with multinational approaches (as a component of a dual track approach).

A key consideration at this stage is whether the country is prepared to be a potential host country. It is not necessary that all countries participating in the multinational project agree to be potential hosts; some non-nuclear power partners, for example, may choose to exclude this option. However, one or more participants must be prepared to leave open the question of siting if the project is to go ahead. Any later agreement to be the actual host would be based on a weighing of the potential benefits and drawbacks — and must of course be voluntary.

The national regulatory and legislative framework should be assessed for effectiveness at both the national and multinational levels, and possible adjustments and amendments identified. In addition, compliance must be checked with all relevant international obligations emanating from treaties, conventions and agreements entered into by the country.

The likely public response to the implementation of a multinational project of this nature should be assessed. Use can be made of opinion surveys and case histories of public reaction to relevant events. A national decision to proceed further with the multinational option will also be influenced by the results of interactions with potential partners in the international waste management community.

### 6.2.2. Multinational activities in advance of a multinational project (step 2)

In this evaluation phase of the project, the participating countries also have to resolve the key principles that need to be mutually agreed before a formal multinational organization can be established. This formal body is termed a MN-RDO and it is intended to act in the capacity of a sister organization to the national WMOs already established nationally. The steps leading to establishment of the MN-RDO are summarized below.

It will be necessary to establish a new multinational working group or else expand the remit of the existing multinational ad hoc working group in order to initiate and coordinate negotiations on the legal form, organizational structure, staffing, work programme and budget of the potential MN-RDO. Although many of these aspects will be definitively decided by the MN-RDO itself once it is established, initial concepts must be agreed as an input for decision making by the potential participating countries. Accordingly, those delegated to the working group at this stage must have the necessary competence to represent their governments.

The working group should at this stage strengthen its links to the international waste management community and especially to national WMOs that might be concerned about potential negative impacts of the multinational initiative.

Agreement must be reached on a basic implementation strategy, including a multinational siting concept (conceptual design, principles for the siting procedure, public involvement). Key issues to be considered and agreed upon are whether all partners should be prepared to be selected as potential hosts, whether countries that do not have NPPs are excused from the host selection process, and whether and under which circumstances countries may opt out of the venture, or further countries may be allowed to opt into the venture.

The working group should also assess the needs for research and development, either as complementary activities to those of national programmes or in direct cooperation with such programmes.

One of the most important tasks of the working group will be the analysis of the economic implications of the multinational approach (total cost, funding requirements and individual shares). For the initiative to succeed, all participants must be convinced of the potential benefit to their countries.

A sensitive issue is likely to be concerned with reaching agreement on a domicile for the MN-RDO. The country of domicile must be a volunteer but it must be made clear that agreeing to host the MN-RDO does not prejudice the later selection of a host country for the repository itself.

## 6.3. PHASE III — INITIATING THE ACTIVITIES OF THE MN-RDO

This phase is initiated by establishing a formal MN-RDO. The MN-RDO is the forum for the partners in the multinational project to finalize all necessary implementation issues before launching a specific repository project. The proposals made by the preparatory multinational working group should be formalized and expanded upon by the MN-RDO. The MN-RDO will be domiciled in one of the participating countries, but, as stated above, the domicile does not prejudice the later selection of a host country for the repository. All of the important issues affecting the operation of the MN-RDO should have been discussed in advance in the prior working group meetings. However, agreements reached in prior meetings have to be formalized as definitive decisions and operations have to be initiated, with all activities now being subject to the law of the chosen MN-RDO domicile. Some of the issues that have to be revisited, formally agreed and also communicated are addressed below.

*Political strategy*: An overall strategy should be developed to address the political expectations at the national level for the multinational project. In particular, in view of the political sensitivity of the multinational project, a coherent public position should be established before the project is officially launched.

*Institutional and legal matters*: The national legal systems of countries should be harmonized in relation to multinational projects. Compatibility among the respective national licensing systems should be achieved. This task can be completed only when the host country is finally selected, but the participating countries in the MN-RDO should begin an in-depth comparison of the relevant national legal waste management frameworks before then.

*Liabilities:* National arrangements to cover liabilities should be developed and harmonized, including nuclear liability regimes, mechanisms for sharing liabilities, ownership of liabilities (e.g. spent fuel and waste), and possible malfunctions. Some of these issues are discussed in Section 4.9. Precedents exist for multinational ownership of nuclear facilities such as power plants or enrichment plants that are hosted by one of the international partners [22–24].

*Nuclear safety and security*: Agreement should be reached on oversight bodies and mechanisms for safety including the establishment of safety and security criteria [3, 4, 25]. In cases where the ultimate host country will be accepting spent fuel containing fissile materials from a number of other countries, it must have good non-proliferation credentials and must also be able to provide the necessary level of security [26]. In addition, the regulatory regime to be applied must be agreed [3, 4]. The regulator in the country hosting the MN-RDO will have a special role, but regulatory bodies in all participating countries may wish to be involved in the development phase. In the implementation phase, the prime regulator will be that of the repository host country, but again, other participants will expect to be involved. In addition, it is conceivable that the multinational repository partners may request that international bodies such as the IAEA have a greater involvement in the oversight.

*Economic and financial arrangements*: Agreement should be reached on project cost estimates, the allocation of costs among the participating countries and financing mechanisms for project execution. Precedents exist for these potentially contentious issues, in that various national waste disposal organizations are owned by independent waste producers, each of which has to agree that the financing schemes adopted are fair to all.

*Social matters*: Public involvement strategies or plans at the national level should be developed with due regard to public communication requirements, articulation of the benefits (notably for the host country and host community), and taking account of cultural sensitivities. A multinational organization domiciled in one country and preparing disposal projects that may be implemented in another country will have to be open, honest and competent in its communication strategy.

*Detailed siting strategy*: A multinational volunteer based siting strategy, along the lines described in the previous section, should be developed.

*Project management*: Agreement should be reached on the composition of a project team, the finalization of project execution procedures, and the definition of an overall project plan and schedule.

At the conclusion of its initial deliberations, the MN-RDO is expected to have defined or obtained the following:

— Consensus that a full repository development programme can be launched;
— A mandate and roadmap to proceed with the implementation of the project;
— A site selection strategy;
— A financial scheme to secure the availability of resources over the course of the implementation stage up to closure of the repository and beyond;
— A clear definition of project requirements: repository capacity, operational lifetime, waste types (including spent fuel) and amounts involved;
— Project management strategy decided; staff selected (staff may be hired directly or their selection may be delegated); structures set; responsibilities defined, and so on.

The MN-RDO will then proceed with the technical and societal programmes needed to take the project through to the stage of identifying the preferred volunteer host country and possibly the actual site.

## 6.4. PHASE IV — ACTIVITIES OF THE MN-RDO UP TO AGREEMENT ON A SPECIFIC HOST COUNTRY

This phase of the project includes all the steps to be taken by the MN-RDO in the staged repository implementation process up to completion of the site selection process. It includes all the activities that would typically form part of a national site selection programme but that are instead applied to several countries in a multinational siting programme.

The siting process is assumed to be managed by the MN-RDO up to the critical milestone when the preferred site is nominated. Once the repository site has been selected and the decision confirmed by the participating countries, the implementing body (referred to here as the multinational repository organization, MN-RO) is established with its domicile in the country hosting the repository site. During the pre-siting period, the MN-RDO has to initiate and sustain technical programmes in a variety of areas analogous to those managed by most national disposal organizations.

### 6.4.1. Inventory databanks

The technical planning, the siting criteria and the financing concept will all depend upon the expected inventory of the multinational repository. Accordingly, the MN-RDO must ensure that all participating countries maintain inventory databanks that classify and quantify all of the waste currently being stored or produced by present nuclear facilities, and that likely to arise from future planned facilities. These individual databases must be made consistent and combined by the MN-RDO into a reliable working database.

#### *6.4.1.1. Repository conceptual design(s)*

Geological repository designs have many similarities despite the diverse geological host formations to which they are applied. In the case of a multinational project, it is necessary to develop more than one conceptual repository design to make provision for the wider range of technical attributes of the potential disposal sites. However, repository surface buildings (e.g. waste reception facilities) may be expected to be very similar in all cases. The geological repository designs should have sufficient flexibility to allow for:

— Miscellaneous spent fuel types from power and/or research reactors;
— Miscellaneous radioactive waste types (HLW, ILW, long lived LLW, etc.), including disused sealed radioactive sources;
— Fluctuations in waste volumes over a long period, e.g. those resulting from nuclear energy programme developments;
— A variety of potential host rocks and siting environments.

#### *6.4.1.2. Safety assessment capabilities*

The MN-RDO should have the capability within its organization or in a closely tied partner organization to perform, understand and communicate safety assessments for repositories.

#### *6.4.1.3. Siting process*

The multinational dimension of site selection implies some degree of harmonization on site evaluation and selection criteria. This includes agreement among the partner countries on the public and environmental protection objectives. In terms of public and environmental protection, the participating countries should agree on common reference principles and policy for radiological protection to be applied to the disposal of radioactive waste [3, 5]. They should also agree on the methodologies for evaluating future repository performance and safety at each candidate site.

In terms of public acceptance, it is important that the participating countries agree that, in running the voluntary siting strategy, the MN-RDO should to be able to:

— Approach the national and/or local constituencies in each country (with appropriate support from nationals of the country);
— Negotiate economic partnerships with the candidate countries and communities;
— Involve the candidate communities in the decision making process, e.g. through public hearings, in compliance with the legislation in each partner country.

*6.4.1.4. Site selection decision*

A possible outcome of the siting process is that several potential sites located in more than one participating country have been identified and demonstrated to be suitable for safe geological disposal. If two or more local communities from two or more countries volunteer to host the future repository, a multi-attribute decision process might be applied by the partners to aid decision making based on the following considerations, among others:

— Technical capability in the country and the region;
— Sociopolitical acceptability in the country and region;
— Opportunities for economic development;
— Institutional and regulatory status;
— Transport requirements.

As part of the process for finalizing the selection of the repository site, it will be necessary for the regulatory body in the host country to formally review and accept the safety case for the selected site. This formalization of the suitability of the selected site is the first step in the subsequent regulatory process leading to the granting of a site licence.

### 6.5. PHASE V — MULTINATIONAL REPOSITORY IMPLEMENTATION AT A SPECIFIC SITE WITHIN THE HOST COUNTRY

The post site selection process starts at the point at which the repository site has been selected in the host country. Subsequent steps in the repository implementation process are similar to the equivalent steps for purely national programmes.

Once the disposal site has been identified and agreed among the participating countries, the repository implementation project can be launched.

This phase of the project should be implemented by the MN-RO, which, as the future licence holder and operator, should be domiciled in the host country. The MN-RO will have to obtain a repository construction licence from the host country regulator, as well as a repository operating licence, including all the other authorizations required to bring the project to completion. Ultimately, the repository has to be closed at the end of its life, for which the MN-RO will need a licence for closure.

The technical activities involved in this part of the project are relatively well understood because of the development work already performed in those countries with advanced national programmes. Hence, it is not considered necessary in this publication to elaborate on the detailed aspects of the repository implementation process.

The political, institutional and societal issues that must be addressed during the operational and closure periods of the multinational repository are, however, likely to be different from those in national programmes. There are precedents for States agreeing to mutually own or operate nuclear facilities [21]. The examples of Eurochemic, Eurodif and Eurenco are discussed in Ref. [23]. In non-nuclear areas, there are also some relevant examples of long term multinational cooperation to fulfil common goals, and a useful model is the European Space Agency [24].

# 7. RISK MANAGEMENT IN THE MULTINATIONAL PROJECT

As a large scale, highly technical and also innovative investment project, which extends over several decades, the multinational project is politically and socially sensitive. For a successful outcome, it will be necessary to manage the associated risks in a professional manner.

## 7.1. PRINCIPLES OF RISK MANAGEMENT

Risk management in the most commonly used approach is defined as “co-ordinated activities to direct and control an organization with regard to risk”, with risk itself being defined as “the effect of uncertainty on objectives” (ISO 31000 [27]). The risk management process is then characterized as a “systematic application of management policies, procedures and practices to the tasks of communication, consultation, establishing the context, identifying, analysing, evaluating, treating, monitoring and reviewing risk”.

The overall method used for risk analysis includes the following steps:

— Identify potential risks;
— Determine the risk (i.e. the expected likelihood and consequences of specific types of events);
— Define ways to reduce those risks;
— Prioritize risk reduction measures based on a strategy.

The above steps are usually preceded by the identification and characterization of the threats involved. Risks relate to events that, when triggered, cause problems. Hence, risk identification can start with the source of problems, or with the problem itself. When either source or problem is known, the events that a source may trigger or the events that can lead to a problem can be investigated.

The strategies for managing the risks include:

— Avoidance (eliminate the risk by withdrawing from the undertaking);
— Reduction (optimize and mitigate);
— Sharing (transfer some risk to partners; outsource or insure);
— Retention (accept risk and allow for it in the budget).

The approach followed in this section is based on problem identification within a particular threat category. This approach helps to organize the different problem or threat areas into more or less homogeneous category clusters for ease of analysis. Risks can come from many different threats, such as, financial markets, project failures, legal liabilities, regulatory delays, political upheavals, accidents, natural causes and disasters, or events with uncertain or unpredictable root causes.

## 7.2. RISKS IN A MULTINATIONAL PROJECT

In view of the complexity of a fully fledged multinational project, it is beyond the scope of the generic analysis in this publication to identify all of the potential risks involved, or to determine the specific risks relating to the project and to describe exact ways in which such risks can be effectively reduced. The same argument rules out the possibility of prioritization of the risks at the current stage. A risk management approach involving all the steps in this methodology is only possible once a detailed multinational project specification is available.

Risks to the multinational project are examined in terms of the following threat categories: technical, economic, institutional and sociopolitical (Fig. 1). Examples of possible disruptive events are highlighted in each of the categories, and the expected impact on project progress and partnership arrangements is briefly noted. This is followed by a summary of the applicable mitigating measures that can be applied. In practice, these risks may involve more than one problem/threat category, or combinations thereof, in which case, the risks are classified under the category that plays the most decisive role in the outcome. It is no surprise that the most obvious and most numerous risks are in the socioeconomic category. This directly reflects the challenges faced by national waste management programmes. The United States National Research Council came to the same conclusion, stating that for national disposal programmes, “Today the biggest challenges to waste disposition are societal” [28].

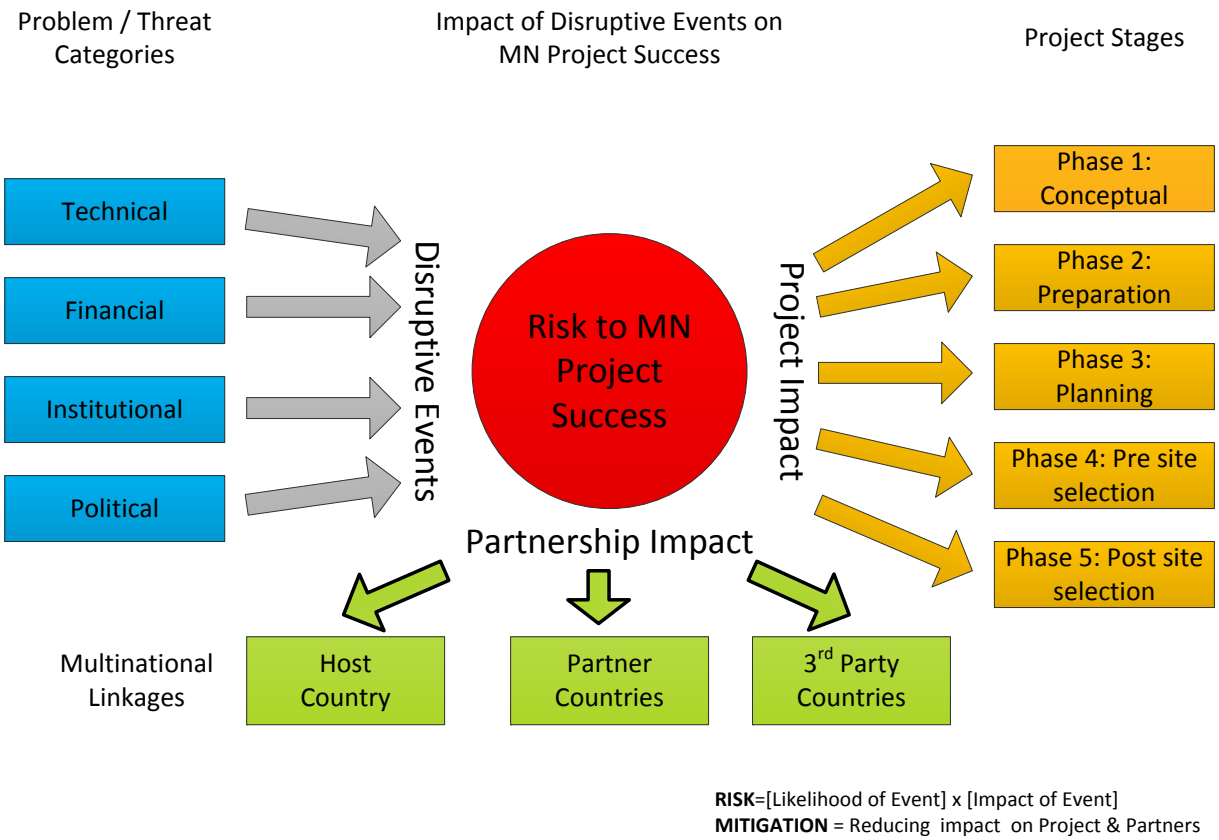


*FIG. 1. Impact of disruptive events on multinational project success.*

In an actual multinational project, a fully fledged risk analysis would have to be carried out and the mitigating measures defined in detail to allow estimates of the risk reduction and the cost of this reduction. Caution has to be exercised to not overcompensate for potential risks. Overcompensation may take the form of excessive mitigating measures that tend to complicate project implementation and potentially add significantly to the overall project cost. Ideally, a balance should be struck between preventive (before the event) and corrective (after the event) mitigating measures in the execution of the project.

It is important to bear in mind that many of the risks identified for multinational projects — and also many of the mitigating measures — are equally applicable to national waste management programmes.

## 7.3. TECHNICAL RISKS

A risk arising within the technical category may have a disruptive effect not only on project progress directly, but also on the partnership arrangement, which in turn may affect project progress.

Multinational projects are designed to evolve logically through the different project implementation phases. During this implementation process, technical issues are systematically addressed and progressively resolved. Hence, it is reasonable to assume that risks falling within the technical category are fairly well under control. But each multinational venture will have its own unique features that have to be analysed in detail. In this discussion, some relatively obvious threats and risks are briefly considered in order to illustrate the approach being followed.

In Table 2, a simple cause and effect relationship is established for each of the risks analysed. It starts with a particular event that gives rise to certain consequences for which mitigating measures are proposed. A mitigating measure can be implemented based on prior anticipation of the consequences, or implemented after the event has occurred in order to ameliorate the consequences.

TABLE 2. EXAMPLES OF TECHNICAL RISKS

| Event | Impact/Consequences | Mitigation |
|---|---|---|
| Unexpected fluctuations in disposal requirements of participants | — Conflict with original contractual agreements entered into between partner countries<br>— Partner countries are unable to dispose of all their waste as originally planned (if inventories increase)<br>— Uneconomic operation (if inventories decrease) | — Build into the contracts specific prohibitions to unilateral reduction of repository disposal volumes<br>— Leave room for re-negotiation of contractual terms where possible<br>— Keep siting options open for as long as possible to accommodate future repository expansion programmes<br>— Provision of a flexible repository design to cope with possible future waste fluctuations |
| Unexpected tightening of waste acceptance criteria (WAC) imposed by host country | — Conflict with original contractual agreements entered into between partner countries regarding multinational WAC<br>— Tightening of WAC leads to cost increases for partner countries | — Build into the contracts specific prohibitions to unilateral WAC variations<br>— Allow room for future negotiations in the contractual agreements to incorporate reasonable requests for future WAC tightening |
| Operational accidents | — Project stopped or delayed<br>— Loss of public trust | — Maintain highest technical standards<br>— Strict oversight with involvement of regulators in partner countries |
| Malfunction of the completed facility | — Expensive remediation measures<br>— Loss of public trust | — Highest technical standards and state of the art siting processes<br>— Strict oversight with involvement of regulators in partner countries |

In a multinational repository project, as in other projects of this nature, it is customary to perform a hazard analysis (mostly for safety reasons) during the design phase of the project. The hazard analysis aims to put in place an effective mitigating strategy to address potential problems.

## 7.4. FINANCIAL RISKS

Financial (or economic) risks involve commercial and cost complications that may influence the viability of the multinational project. The likelihood of financial risks may be increased by the lengthy project implementation timeframes involved. The selected examples presented in Table 3 are potentially serious and require adequate provision in the contractual arrangements at the outset of the project. Not only may project delays be involved, but the partnership may also be detrimentally affected. There are many other events of this nature that need to be analysed at the project planning stage, depending on the needs and preferences of the partnership involved.

TABLE 3. EXAMPLES OF FINANCIAL RISKS

| Events | Impact/Consequences | Mitigation |
|---|---|---|
| Participants postpone transfers to repository because waste is in national stores | — Revenue stream insufficient to cover running costs | — Provide cost incentives for timely transfers<br>— Penalize partners for non-use of allocated capacity in the repository |
| Unexpected disposal tariff increases imposed by host country | — Partner countries find tariff increases unaffordable | — Make provisions in contractual arrangements for excluding such increases unless negotiated and agreed |
| Unexpected financial difficulties experienced by partners to meet multinational commitments | — Partner countries wish to withdraw from multinational project<br>— Partners withdrawing from the project tends to reduce the benefits of economies of scale | — Contractual guarantees may encourage continued participation<br>— Provision for entrance fees/penalty clauses in contracts for withdrawal from the multinational undertaking<br>— Allowing extension of timeframes where expedient<br>— Entry conditions to require sound financial schemes to protect segregated funds set aside for specific multinational purposes |
| Escalation in implementation costs | — Funding allocated by participants is insufficient<br>— Contentious debates about responsibility for overruns | — Conservative cost estimates with realistic contingencies<br>— Point to responsibility of all participants to agree these estimates<br>— Tight monitoring and control of costs by multinational oversight committee |

## 7.5. INSTITUTIONAL RISKS

Institutional risks can arise from difficulties in meeting legal and regulatory requirements within a partner country. These difficulties must be resolved in conjunction with the competent authorities responsible for the implementation of the national regulatory regime. In this regard, the multinational project will be dependent on the successful implementation of the regulatory systems in the individual partner countries, with the host country regulator naturally playing a decisive role.

The examples presented in Table 4 concerning regulatory non-compliance and the imposition of more stringent regulations reflect possible future events for the multinational project. The approach to resolving such risks should be well developed at the national level where the impact of regulatory difficulties will occur and where they have to be resolved. The multinational project is particularly vulnerable to serious regulatory problems arising in one or more of the partner countries. If such problems are not adequately resolved in a timely fashion, they may seriously affect the overall performance of the multinational project. This is especially true for the host country.

TABLE 4. EXAMPLES OF INSTITUTIONAL RISKS

| Events | Impact/Consequences | Mitigation |
|---|---|---|
| Legal challenges to siting or licensing in host country | — Delays and cost overruns | — Intensive scrutiny of all relevant legislation before choosing sites or submitting licence applications<br>— Transparent information policy that encourages early identification of potential contentious issues |
| Changes in laws of host country after siting | — Delays or abandonment of project | — Ensure government level consent at outset and a full set of government to government bilateral agreements |
| Failure of multinational project to meet overall safety requirements | — Non-conformance with safety requirements resulting in withdrawal of licences<br>— Imposition of more stringent safety regulations and standards within the participating countries | — Ensure regulatory cooperation among the participating countries as a means of resolving future regulatory conflicts<br>— Strict adherence to safety requirements and commitment to a sound safety culture from operators<br>— Maintain transparency in public communication when reacting to media coverage of non-compliance |
| More stringent regulations imposed by national regulators of participating countries | — Delays in transfer of waste packages and/or disposal implementation<br>— Increased costs due to more labour intensive practices related to new regulations | — Ensure that national regulators from partner countries become involved in the project from the beginning<br>— Require formal sign-off on applicable regulations by regulators in all participating countries |

## 7.6. SOCIOPOLITICAL RISKS

Political risks are not only unpredictable, but are generally the least controllable. As a means of ensuring ongoing political and public support, a voluntary approach including a wide range of stakeholders in each participating country should be followed as far as possible. This may make it more feasible to accommodate swings in public opinion, which cannot be excluded, even after firm commitments to expedite the project have been made. In this regard, it must be noted that public opinion will be influenced by political opinions, which to a large extent reflect public views, and that complex interactions can result. The media will also influence public perceptions of the multinational project. Experience in national waste disposal programmes has shown that political decisions can lead to the failure of even mature, established repository programmes, as was the case with the Yucca Mountain project in the USA. Experience has also shown that citizen protest can delay or stop projects that have political and legal consent, as has happened in France, Germany and Switzerland in the past. A complicating factor for multinational projects is that, in the political arena, debate on a multinational facility may well be mixed with many other issues affecting interactions among participating countries.

For the examples given in Table 5, there is a parallel between multinational projects and national programmes for countries where there are sub-national entities such as states, counties or cantons with a large degree of autonomy which must coordinate their activities to seek resolution of the waste disposal issue.

TABLE 5. EXAMPLES OF SOCIOPOLITICAL RISKS

| Events | Impact/Consequences | Mitigation |
|---|---|---|
| No volunteer countries offer to host repository | — Multinational project cannot go ahead<br>— This difficulty would typically arise at the end of Phase IV of the project, i.e. after completion of site characterization work and before the selection process begins | — Re-examine the outcome of the siting studies and resolve any possible misunderstandings<br>— Make the incentives for hosting very clear and allow the host to negotiate these<br>— Invite more than one volunteer as a means of taking the focus off a single volunteer |
| One or more participating countries withdraw from multinational venture | — Project's economic viability compromised by withdrawals<br>— Durability of long term multinational cooperation compromised | — Emphasize benefits of multinational cooperation for partner countries regarding incentives of cost sharing and economies of scale<br>— Emphasize examples of successful multinational cooperation<br>— Defer decision on host country selection until problematic issues have been resolved<br>— Specify at the outset the point up to which withdrawal with no repercussions is allowed, after this, there could be financial penalties |
| National elections in which multinational project is an issue (host and partner countries) | — The multinational project becomes an election issue with politicians perceiving that support can be won by opposing the multinational project | — Ensure cross-party support in participating countries<br>— Early, sustained and prominent information on the benefits of participating in the multinational project and, in particular, of acting as host<br>— Agree long term binding contracts, penalty clauses etc. aimed at discouraging policy changes that may jeopardize the future viability of the project |
| Societal opposition (public acceptance, litigation) | — Delays and cost overruns in the project<br>— Loss of political support<br>— Negative public image for the project | — Ensure that the public participation programme is well designed and executed<br>— It is especially important that the multinational programme be properly launched<br>— Maintain close collaboration with the volunteer host community that will lose out if the project fails<br>— Societal acceptance may also be enhanced by pointing out that the alternatives to a multinational project are going it alone (which is expensive) or having no solution (which is irresponsible) |
| National disposal programmes slowed or stopped because of changing priorities | — Cheaper short term alternatives such as extended storage are favoured<br>— Pressure from national waste management bodies to cut any multinational projects before national projects are cut | — International organizations continue to stress requirements on States to provide a disposal solution<br>— International organizations continue to stress that the solution can be a multinational approach |
| Neighbouring country does not allow transports through territory, either for legal reasons (ban on transport) or to avoid social disruption | — Delays<br>— Negative image for project | — Emphasize international agreements on freedom of transit for goods<br>— Early integration of neighbours into multinational project discussions |

TABLE 5. EXAMPLES OF SOCIOPOLITICAL RISKS (cont.)

| Events | Impact/Consequences | Mitigation |
|---|---|---|
| Reduced consensus of desirability of disposal solution (new technology, changing in ethical approach) | — Push for extended storage | — Public information on scientific consensus on the safety of geological disposal<br>— Public information on scientific consensus on the need for geological disposal in any future nuclear scenario |

# 8. CONCLUSION

This publication is the fourth in the series of IAEA investigations into the feasibility of establishing a multinational repository. The first publication [6], issued in 1998, concentrated on the technical, economic, institutional, political and social aspects of such a multinational project. The second publication [7], finalized in 2004, examined the infrastructural requirements for multinational repositories as well as possible scenarios of cooperation between participating countries. The third publication [8] considered the viability of specific proposals that have been put forward for a multinational repository. The emphasis in this publication, the fourth study, is on identifying the institutional requirements for the development of an implementation framework for a multinational cooperation scenario. In all four publications, although the results are applicable to a wide spectrum of waste types, cooperation possibilities and disposal options, the main focus has been on geological disposal of long lived radioactive waste and, in particular spent fuel and HLW. The work presented here found that the general conclusions from these publications remained valid and these are therefore summarized in the following paragraphs.

There are almost no challenges faced by multinational disposal initiatives that are not also faced by purely national disposal programmes in democratic countries. All of the technical, economic and sociopolitical hurdles faced by multinational initiatives have been addressed by a national programme somewhere in the world. The technical and economic challenges may in fact be more easily addressed by multinational partners than by a single, possibly small, nation on its own. For the sociopolitical issues involved in multinational volunteer siting, experience can be gained from volunteer siting in States with powerful sub-units. (Examples are states in the USA, cantons in Switzerland and counties in the UK.) Nevertheless, the political and societal challenges in multinational projects are undoubtedly greater.

The country or countries that finally decide to volunteer as hosts must be fully convinced that the political, economic and societal benefits outweigh any real or perceived drawbacks. Sufficient support from all stakeholder groups is required, given the long term nature of the commitments involved.

The time frame for the realization of multinational geological repositories is uncertain. The uncertainties are principally of a sociopolitical nature, but they also have a technical side. Progress towards the establishment of geological repositories in most countries with nuclear power has been slow and hence it can be argued that the safety and technical durability of these facilities still need to be demonstrated.

It will be necessary for countries participating in a multinational repository project to build certain mitigation measures into their implementation strategy as protection against the risks inherent to a project of this nature. In many instances, these mitigation measures are also applicable to the national strategy.

It is not necessary for countries to make an early commitment to share repositories. An attractive approach is to keep the option of multinational cooperation open, while actively developing and implementing a national strategy for radioactive waste management and developing national skills in this area. This dual track approach should be followed until either a national or a multinational solution has been implemented.

A multinational repository could be a viable undertaking, and could offer substantial benefits to the countries involved. One of the main benefits is in the economic advantages accruing from a combined disposal operation. The potential enhancement of global nuclear safety and security may also be seen as an advantage. Other positive aspects are concerned with resource sharing, such as the pooling of research and development expertise, technical problem solving capability, repository siting experience and facility design know-how.

## Appendix I

## RELEVANT IAEA ACTIVITIES AND DOCUMENTATION

The IAEA has issued a number of publications relating to the feasibility of implementing multinational repositories.

IAEA TECDOC 1021: Technical, Institutional and Economic Factors Important for Developing a Multinational Radioactive Waste Repository, published in 1998 [6]. The publication concluded that the multinational concept was not in conflict with the generally accepted ethical position relating to waste management. It further concluded that economies of scale would be a major benefit for participating countries and that nuclear materials transport would not significantly impact public health.

IAEA TECDOC 1413: Developing Multinational Radioactive Waste Repositories: Infrastructural Framework and Scenarios of Cooperation, published in 2004 [7]. The publication discussed issues relating to the implementation of multinational repositories. It endorsed the findings of the first publication and came to the conclusion that multinational repositories could enhance global safety and security, in addition to offering significant global advantages.

IAEA TECDOC 1658: Viability of Sharing Facilities for the Disposition of Spent Fuel and Nuclear Waste — An Assessment of Recent Proposals, published in 2011 [8], includes the most recent proposals and discusses under which conditions these could be viable approaches.

IAEA TECDOC 1482: Technical, Economic and Institutional Aspects of Regional Spent Fuel Storage Facilities, published in 2005 [9]. Concurrently with the studies on multinational repositories, the IAEA also undertook an investigation into the feasibility of regional spent fuel storage. Although the storage and disposal concepts are different, there is nevertheless a link between them: long term storage of radioactive waste is the precursor to disposal. This study also confirmed the potential viability of the regional storage concept.

In the IAEA publication Multilateral Approaches to the Nuclear Fuel Cycle, published in 2005 [10], multilateral approaches to enrichment, reprocessing and disposal were examined. The publication concluded that the IAEA will ideally continue its efforts to work on the underlying factors in support of multilateral approaches to spent fuel disposal and in addition could assume political leadership to encourage such undertakings.

The publication Options for Management of Spent Nuclear Fuel and Radioactive Waste for Countries Developing New Nuclear Power Programmes [29] looked at all the national and multinational options that a country embarking on a nuclear programme could consider for managing its spent nuclear fuel. It suggests that countries follow a dual track approach consisting of developing national waste disposal facilities and, at the same time, studying possibilities for developing multinational shared ones.

Major findings of the INPRO (International Project on Innovative Nuclear Reactors and Fuel Cycles) dialogue forum Drivers and Impediments for Regional Cooperation on the Way to Sustainable Nuclear Energy Systems are summarized on-line [30]. This forum looked at all of the challenges facing new nuclear energy users. Among its conclusions were that collaboration can be valuable in waste minimization procedures, characterization, treatment, storage and disposal. Moreover, a key focus could be on shared development of the ultimate waste repository and optimization of repository capacity.

## Appendix II

## OTHER DEVELOPMENTS RELEVANT TO MULTINATIONAL APPROACHES

### II.1. EUROPEAN UNION WASTE DIRECTIVE

On the 19th of July 2011, the European Union adopted a Directive [11] establishing a community framework for the responsible and safe management of spent fuel and radioactive waste. In the context of this publication, it is relevant to note the implications for European (and other) initiatives for shared regional repositories. The main message is that the option of European Union Member States sharing repositories is kept open by Clause 4 in Article 4 on General Principles which states that:

> "Radioactive waste shall be disposed of in the Member State in which it was generated, unless at the time of shipment an agreement, taking into account the criteria established by the Commission in accordance with Article 16(2) of Directive 2006/117/Euratom, has entered into force between the Member State concerned and another Member State or a third country to use a disposal facility in one of them" [11].

This implies that regional cooperation could be an important aspect of the detailed plans that the European Commission expects Member States to produce within four years. The preamble to the Directive [11] contained key statements:

> "Cooperation between Member States and at an international level could facilitate and accelerate decision-making through access to expertise and technology...Some Member States consider that the sharing of facilities for spent fuel and radioactive waste management, including disposal facilities, is a potentially beneficial, safe and cost-effective option when based on an agreement between the Member States concerned."

Nevertheless, the binding text of the Directive [11] emphasizes that countries should not use the prospects of regional disposal as a justification for remaining inactive. It states that:

> "Member States shall establish and maintain national policies on spent fuel and radioactive waste management. Without prejudice to Article 2(3), each Member State shall have ultimate responsibility for management of the spent fuel and radioactive waste generated in it."

### II.2. SAPIERR II (STRATEGIC ACTION PLAN FOR IMPLEMENTATION OF EUROPEAN REGIONAL REPOSITORIES)

In mid-2003, Arius (the Association for Regional and International Underground Storage) initiated the SAPIERR project for European regional repositories, which obtained European Commission approval. The work allowed potential options for regional collaboration and for regional repositories to be identified, though it did not extend to site identification. Decom, Slovakia, coordinated the project. Following this pilot study, a new European Commission funded SAPIERR project (SAPIERR II) [12] to assess the feasibility of European regional waste repositories commenced in September 2006. The tasks were:

- To prepare a management study on the legal and business options for establishing a multinational repository organization;
- To study the legal liability issues of international waste transfer within Europe;
- To study the potential economic implications of European regional storage facilities and repositories;
- To perform an outline examination of the safety and security impacts of implementing one or two regional stores or repositories relative to a large number of national facilities;

— To review public and political attitudes in Europe towards the concept of shared regional repositories;
— To development a strategy and a project plan for the work of the multinational organization.

Organizations from numerous European countries participated in the SAPIERR project and, at its conclusion, several of these countries joined ERDO-WG, which is described in Section II.3 below.

## II.3. ERDO-WG (EUROPEAN REPOSITORY DEVELOPMENT ORGANIZATION WORKING GROUP)

Following the initial studies, the European region was identified as the most promising starting place for concrete planning. A political framework already existed, the European Parliament had expressed positive views, and a binding Waste Directive of the European Commission explicitly included sharing facilities between Member States as an acceptable approach to fulfilling waste management responsibilities. Accordingly, the ERDO-WG was formed with the mission of preparing the groundwork for a truly multinational WMO [13]. The national waste management strategy favoured by ERDO-WG members is a dual track approach in which a national disposal concept is pursued in parallel with working with partner countries to assess the feasibility of implementing shared multinational facilities. The dual track approach has been explicitly proposed by the ERDO-WG. Ten European Union Member States (Austria, Bulgaria, Denmark, Ireland, Italy, Lithuania, the Netherlands, Poland, Slovakia and Slovenia) have been involved in ERDO-WG activities. All of these countries have either small nuclear programmes or long lived radioactive wastes from other nuclear technologies, and thus require access to a geological repository. At the end of 2011, the ERDO-WG reacted to the publication of the European Commission Radioactive Waste Directive (which acknowledges the possibility of European Union Member States sharing disposal facilities) by submitting to European Union governments structured proposals for a multinational European WMO. The proposals were sent to countries that have shown direct interest in multinational facilities. They were also sent for information to all of the other European Union Member States. Currently, bilateral and multilateral discussions are in progress in Member States. In the meantime, the ERDO-WG members are already collaborating actively on consideration of common waste management issues. Discussion documents worked on to date have been devoted to the following topics:

— Siting strategies for repositories;
— Size and form of WMOs;
— Outreach activities;
— ERDO Operating Guidelines;
— ERDO Model Constitution.

The key issues that will determine the success or otherwise of the ERDO initiative are the political and public acceptance of transferring spent fuel to another country and the economic benefits that can be derived from multinational cooperation.

## II.4. ARIUS (ASSOCIATION FOR REGIONAL AND INTERNATIONAL UNDERGROUND STORAGE) [14]

Arius was set up in 2002 as a non-commercial body to promote the concept of regional and international facilities for the storage and disposal of all types of long lived nuclear waste. One of its key objectives is to explore ways of providing shared storage and disposal facilities for smaller users. Membership is open and comprises countries with small nuclear programmes as well as industrial organizations with relevant interests. Arius has been instrumental in the setting up of the SAPIERR projects and currently provides the secretariat for the ERDO-WG. Arius has also taken steps to present the European project to other groups in Arab regions and in South-east Asia. In 2012, workshops on Regional Collaboration on Radioactive Waste Management in MENA [Middle East and North Africa] Countries were organized by the IAEA and Arius, with significant input from the Arab Atomic Energy Agency, in Tunisia and the United Arab Emirates. These two workshops made it clear that the priorities in those Arab regions with active nuclear power development differ significantly from those in less wealthy Arab states that are concerned mainly with ensuring safe storage and disposal of spent radiation sources, naturally occurring

radioactive material and other materials. In both cases, however, there is a strong interest in partnering initiatives that pool resources and benefit from economies of scale. In the six countries comprising the Gulf Cooperation Council region, which includes two nations with expanding nuclear power programs (the United Arab Emirates and Saudi Arabia), consideration is also being given to launching a joint project on the feasibility of shared storage and/or disposal facilities. Arius has also been involved in discussions among countries in South-east Asia that are interested in moving into nuclear power and, accordingly, need to establish credible waste management strategies.

## II.5. GNPI (GLOBAL NUCLEAR POWER INFRASTRUCTURE)

In January 2006, the Russian Federation proposed the Global Nuclear Power Infrastructure initiative [15]. This was planned to include four kinds of cooperation: the creation of international uranium enrichment centres, international centres for reprocessing and storing spent nuclear fuel, international centres for training and certifying nuclear power plant staff, and an international research effort on proliferation-resistant nuclear energy technology. The international nuclear fuel cycle centres (INFCC) would be under joint ownership and co-management. They would be commercial joint ventures (that is, without State financing), with advisory boards consisting of government, industry and IAEA professionals. The IAEA would not have a vote on these boards, but would play an advisory role, while also certifying fuel provision commitments.

As a first step, the Russian Federation, jointly with Kazakhstan, established the International Uranium Enrichment Centre at the Angarsk Electrolysis Chemical Complex in 2007 by expanding the enrichment plant in the city of Angarsk (Irkutsk region). Recipient countries receive fuel cycle services, but access to sensitive technology remains in the hands of the supplier State. Ukraine is to use uranium enriched at the International Uranium Enrichment Centre in Siberia, in which Ukraine holds a 10% stake. Armenia has also agreed to take a similar stake in the enrichment facility.

## II.6. IFNEC (INTERNATIONAL FRAMEWORK FOR NUCLEAR ENERGY COOPERATION)

Proposals offering countries access to nuclear power and thus to the fuel cycle have ranged from requesting formal commitments from these countries to refrain from using sensitive enrichment and reprocessing technology, to a de facto approach in which states would not operate fuel cycle facilities but make no explicit commitments, to no restrictions at all. Countries that joined the Global Nuclear Energy Partnership (GNEP) led by the USA, which is now known as the International Framework for Nuclear Energy Cooperation (IFNEC) [17], signed a statement of principles that represented a shift in US policy by not requiring participants to forgo domestic fuel cycle programs. The current IFNEC mission statement is:

> “The International Framework for Nuclear Energy Cooperation provides a forum for cooperation among participating states to explore mutually beneficial approaches to ensure the use of nuclear energy for peaceful purposes proceeds in a manner that is efficient and meets the highest standards of safety, security and non-proliferation. Participating states would not give up any rights and voluntarily engage to share the effort and gain the benefits of economical, peaceful nuclear energy” [17].

Whether developing states will find existing proposals attractive enough to forgo their inalienable right to develop nuclear technology for peaceful purposes remains to be seen.

GNEP was transformed into IFNEC in 2010 and has continued as an international fuel cycle forum, but former plans for constructing nuclear fuel reprocessing and recycling facilities in the USA have been halted. Instead, the current policy is to support fundamental research on a variety of potential waste management technologies. Other ideas addressing the potential global expansion of nuclear fuel cycle facilities include placing all enrichment and reprocessing facilities under multinational control, developing new nuclear technologies that would not produce weapons usable fissile material, and developing a multinational waste management system. Various systems of international fuel supply guarantees, multilateral uranium enrichment centres and nuclear fuel reserves have also been proposed.

## Appendix III

## SUMMARY OF MULTINATIONAL PROJECT MILESTONES

TABLE 6. MULTINATIONAL PROJECT IMPLEMENTATION MILESTONES

| Category | Phase I | Phase II | | Phase III | Phase IV | Phase V |
|---|---|---|---|---|---|---|
| | Conceptual | Preparation | | Initiating MN-RDO | Implementation | Implementation |
| | | National level | Multinational level | | Before site selection | After site selection |
| Feasibility studies | — Feasibility studies by ad hoc working group<br>— Define potential multinational implementation scenarios<br>— Define potential benefits and challenges<br>— Define incentives for pursuing multinational approach<br>— Define key issues to be resolved<br>— Outline possible implementation strategy | Check compatibility of all feasibility studies with national policies, plans and requirements | | | Studies demonstrating capabilities to design repositories for different geologies and to analyse safety | |
| Policy (Political level) | A national policy is in place<br>Multinational option is not excluded | Government decision to consider a multinational repository as one of the options | Government to decide to pursue multinational option | Finalize and publicize the policy of the MN-RDO | Ensure that national policies remain in alignment with the multinational approach in a dual track policy | |

TABLE 6. MULTINATIONAL PROJECT IMPLEMENTATION MILESTONES (cont.)

| Category | Phase I | Phase II | | Phase III | Phase IV | Phase V |
|---|---|---|---|---|---|---|
| | Conceptual | Preparation | | Initiating MN-RDO | Implementation | Implementation |
| | | National level | Multinational level | | Before site selection | After site selection |
| Strategy | A national strategy is in place<br>Multinational option is not excluded | — Define current and future waste management requirements at national level<br>— Review and revise if necessary | — Establish links with potential partners internationally<br>— Agree a basic multinational implementation strategy including a multinational siting concept | Finalize and publicize strategy at national and multinational level | Ensure that national strategies stay aligned with the multinational approach in a dual track strategy | |
| Organizational structures | An ad hoc group can initiate these conceptual studies | Establish a national evaluation team | — Establish a multinational WG to assess multinational project<br>— Establish links to international community | Establish MN-RDO | — MN-RDO to perform siting work<br>— When site is chosen, finalize appropriate form of the MN-RO | Establish MN-RO for licensing, facility construction and operation |
| Institutional | | — Assess institutional framework for national waste management<br>— Assess compliance with international obligations: treaties, conventions | Prepare proposals for compatibility of regulation and legislation to multinational approach | — Ensure harmonization and compatibility of institutional aspects<br>— Determine the role of international institutions in the multinational project<br>— Develop a mechanism for sharing liabilities<br>— Agree oversight bodies for safety and security | — Establish bi/multilateral arrangements<br>— Establish contractual responsibilities and obligations | Obtain licence authorization |

TABLE 6. MULTINATIONAL PROJECT IMPLEMENTATION MILESTONES (cont.)

| Category | Phase I | Phase II | | Phase III | Phase IV | Phase V |
|---|---|---|---|---|---|---|
| | Conceptual | Preparation | | Initiating MN-RDO | Implementation | Implementation |
| | | National level | Multinational level | | Before site selection | After site selection |
| Legislation/ Regulation | | Assess and define necessary legal and regulatory framework for national waste management | Prepare proposals for compatibility of legislation and regulation with multinational system | Harmonize national legislation and regulation for multinational compatibility | Check specific legislation in the chosen host country | |
| Economic and financial | | | Assess economic and financial implications of multinational approach | — Estimate costs<br>— Allocate costs<br>— Establish financing mechanisms<br>— Develop benefits packages for potential hosts | Negotiate and agree final benefits package for host | Agree financial terms on which new users may be accepted |
| Technical | Assess potential safety, security and environmental benefits of multinational option | Assess the technical requirements and capabilities at the national level | Assess R&D requirements | | — Develop alternative conceptual repository designs<br>— Allow flexibility in designs for adaptation to different waste types and volumes<br>— Utilize available R&D | |
| Social | | Assess likely sociopolitical implications | | — Develop public involvement strategy<br>— Articulate benefits for host country | — Adopt a volunteer siting approach<br>— Employ communication teams including representatives of MN-RDO and of the relevant national WMO | |

TABLE 6. MULTINATIONAL PROJECT IMPLEMENTATION MILESTONES (cont.)

| Category | Phase I | Phase II | | Phase III | Phase IV | Phase V |
|---|---|---|---|---|---|---|
| | Conceptual | Preparation | | Initiating MN-RDO | Implementation | Implementation |
| | | National level | Multinational level | | Before site selection | After site selection |
| *Project Activities:* Project management | | | Agree project implementation principles | — Agree project management requirements, strategy and plan<br>— Establish project management team<br>— Provide resources for project execution | | |
| Siting | | | Agree siting concept: conceptual design, siting procedure principles and public involvement | Agree and publicize a detailed siting strategy | — Adopt a volunteering siting approach<br>— Siting process: four stages<br>— Allow for several sites in one country<br>— Harmonize site evaluation and selection criteria<br>— Select and confirm a final site | |
| Facilities | | | | The MN-RDO will need to be domiciled in a participating country and will need a certain infrastructure | | — Construct repository facilities,<br>— Commission and operate facilities<br>— Close repository |

## Appendix IV

## SUMMARY OF THE MAIN ISSUES INVOLVED IN IMPLEMENTING NATIONAL OR MULTINATIONAL REPOSITORIES

Primarily for the benefit for policy and decision makers not involved on a day to day basis with the issues involved in implementing repositories, Table 7 attempts to pose and answer the key questions that may arise during the implementation of national or multinational repositories.

TABLE 7. MAIN QUESTIONS THAT MAY ARISE DURING THE IMPLEMENTATION OF NATIONAL OR MULTINATIONAL REPOSITORIES

| Questions | Answers |
|---|---|
| What is the challenge? | The difficulty is to ensure that highly active long lived radioactive waste remains in a safe condition in the long term (over thousands of years).<br>Protection of human health and the environment is required on a continual basis. |
| What is the solution? | The only long term solution is permanent isolation of the waste in a deep geological repository.<br>Long lived waste can be temporarily stored, but ultimately it needs to be disposed of in a geological repository. |
| What is a deep geological repository? | A deep geological repository is a facility that is constructed a few hundred metres underground in which the waste is permanently disposed of. |
| How does one construct such a repository? | There are a number of steps in the process of constructing a geological repository. The main steps are:<br>— Find a geological host rock situated deep underground that is suitable for the construction of the repository<br>— Provide access shafts down to the host rock to be able to construct an underground system of corridors and cavities for the disposal of the waste packages<br>— Prepare the waste packages above ground, move the packages into the repository and secure them in fixed positions provided for this purpose<br>— Backfill the repository at the end of its operating life to the extent necessary to allow for retrievability of the waste<br>— Carry out a post-closure safety assessment on the repository, and if successful, declare it to be safe for long term institutional control |
| How does one go about the task? | There are two options:<br>*Option 1:* Each country builds its own deep geological repository for its exclusive use, i.e. a national repository.<br>Each country accepts sole responsibility for the disposal of its own waste.<br>*Option 2:* Several countries cooperate with the aim of building a repository in one of the countries for use by all the participating countries, i.e. a multinational repository.<br>Participating countries share the responsibility for the disposal of their combined waste in a single repository built in one of the countries. |

TABLE 7. MAIN QUESTIONS THAT MAY ARISE DURING THE IMPLEMENTATION OF NATIONAL OR MULTINATIONAL REPOSITORIES (cont.)

| Questions | Answers | |
|---|---|---|
| What are the pros and cons? | Option 1: | |
| | *Pros:* Each country retains full control of the national repository project at all times<br>Each country can, at any stage of the project, make changes to it, or even discontinue the project altogether | *Cons*: Each country needs to mobilize all the required resources for implementing the national repository project<br>Each country needs to bear the full capital and operating cost burden for the implementation of the repository |
| | Option 2: | |
| | *Pros*: Participating countries can pool their resources to build the shared repository<br>Participating countries can share the financial burden and also derive benefits from the economy of scale of the joint project | *Cons*: Participating countries are vulnerable to members withdrawing from the joint project at any stage<br>Withdrawal of participating countries reduces the effectiveness of the joint project and shifts the burden to the remaining members |
| How does one arrive at the best strategy for a country? | There are two possibilities:<br>(1) A purely national repository strategy is followed<br>(2) Dual track strategy is developed and followed | |
| How does one implement the multinational strategy, if chosen? | There are five phases in implementing the process:<br>*Phase I*: Several countries agree to explore the possibility of cooperating in a multinational approach<br>Feasibility studies are performed by the prospective participating countries on the implications of a joint repository project<br>*Phase II:* Each prospective participating country defines a national strategy, and then proceeds to determine the impact of multinational requirements, if imposed on the national waste management system<br>*Phase III*: Project planning<br>Complete with all participating countries the planning necessary for the multinational project implementation<br>*Phase IV*: Project execution<br>Before site selection: Complete all activities associated with site selection process, select a site and hence a host country<br>*Phase V*: Project execution<br>After site selection: Complete all activities involved in the construction and operation of the repository | |
| What are the critical success factors for a multinational approach?<br><br>(not listed in order of priority) | — Clearly defined benefits for participating countries<br>— An agreed need for cooperation among the participating countries<br>— A willing host country capable of taking the lead in the repository project execution<br>— Public confidence in and acceptance of the project, especially within the host country<br>— Compliance with all safety requirements and ensuring the confidence of the responsible regulators<br>— A well developed siting strategy implemented with commensurate sensitivity<br>— A robust contractual framework that is binding on the participating countries and encourages continued future cooperation<br>— Support and endorsement from the international nuclear community<br>— Well developed national strategy for waste management among the participating countries | |

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# ABBREVIATIONS

| | |
|---|---|
| ARIUS | Association for Regional and International Underground Storage |
| ERDO | European Repository Development Organisation |
| GNEP | Global Nuclear Energy Partnership |
| GNPI | Global Nuclear Power Infrastructure |
| HLW | high level waste |
| IFNEC | International Framework for Nuclear Energy Cooperation |
| ILW | intermediate level waste |
| INPRO | International Project on Innovative Nuclear Reactors and Fuel Cycles |
| LLW | low level waste |
| MN-RDO | multinational repository development organization |
| MN-RO | multinational repository organization |
| NPP | nuclear power plant |
| SAPIERR I | Support Action: Pilot Initiative for European Regional Repositories |
| SAPIERR II | Strategic Action Plan for Implementation of European Regional Repositories |
| URL | underground research laboratory |
| WAC | waste acceptance criteria |
| WMO | national waste management organization |

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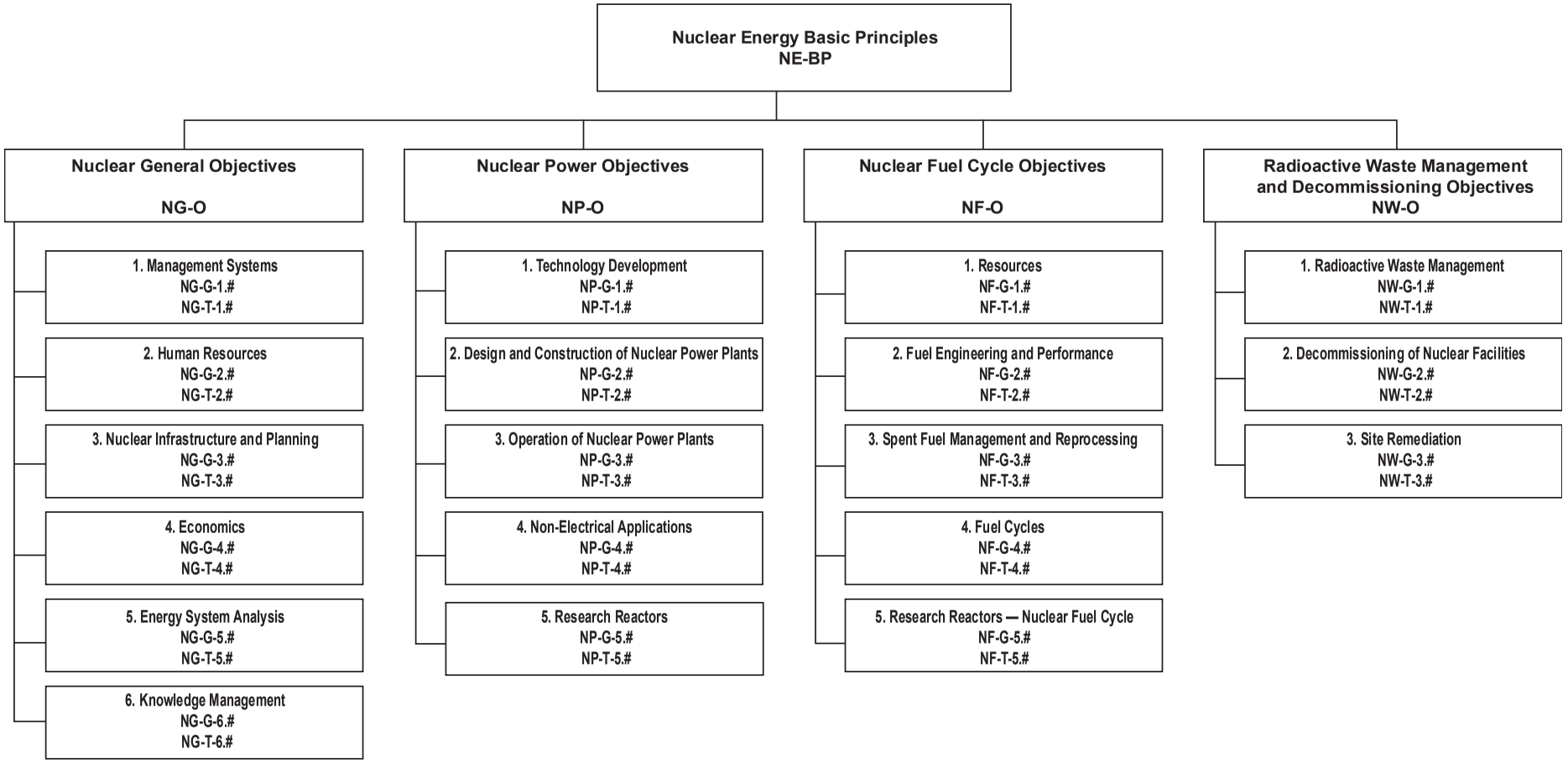


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