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Policies and Strategies for Radioactive Waste Management

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POLICIES AND STRATEGIES FOR RADIOACTIVE WASTE MANAGEMENT

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POLICIES AND STRATEGIES FOR RADIOACTIVE WASTE MANAGEMENT

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FOREWORD

The IAEA assists its Member States in managing spent fuel and radioactive waste in a safe and responsible manner by developing international standards and disseminating proven technical approaches. As part of these efforts, the IAEA provides guidance to its Member States on establishing national radioactive waste management policies and relevant strategies; this guidance is also relevant to spent fuel after it is declared as waste.

After nuclear technologies have been initiated, some form of waste management has to be introduced. However, in many Member States, waste management is not organized in a systematic way. Ideally, countries should have a national policy and a technical strategy, or strategies, for the management of radioactive waste. The two components 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, their development should be closely coordinated.

The contents of spent fuel and radioactive waste management policy and strategy, and their development, are the main subjects of this publication. It is intended to help in facilitating proper and systematic planning, and safe implementation of all waste management activities. This guide is aimed at strategic planners, waste managers, operators of waste management facilities and regulators.

This publication offers options and indicates approaches for spent fuel and radioactive waste management. It presents a unified understanding of radioactive waste management policy and strategy matters. The IAEA wishes to express its appreciation to everyone who took part in the preparation and publication of this guide, in particular G. Linsley, United Kingdom, who chaired preparatory meetings, and drafted and edited the text.

The IAEA officers involved in the preparation of this publication were L. Jova Sed of the Division of Radiation, Transport and Waste Safety, and Z. Drace and L. Nachmilner (the officer responsible for the publication) of the Division of Nuclear Fuel Cycle and Waste Technology.

EDITORIAL NOTE

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CONTENTS

SUMMARY

A policy for spent fuel and radioactive waste management should include a set of goals or requirements to ensure the safe and efficient management of spent fuel and radioactive waste in the country. Policy is mainly established by the national government and may become codified in the national legislative system. The spent fuel and radioactive waste management strategy sets out the means for achieving the goals and requirements set out in the national policy. It is normally established by the relevant waste owner or nuclear facility operator, or by government (institutional waste). Thus, the national policy may be elaborated in several different strategy components. To ensure the safe, technically optimal and cost effective management of radioactive waste, countries are advised to formulate appropriate policies and strategies.

A typical policy should include the following elements: defined safety and security objectives, arrangements for providing resources for spent fuel and radioactive waste management, identification of the main approaches for the management of the national spent fuel and radioactive waste categories, policy on export/import of radioactive waste, and provisions for public information and participation. In addition, the policy should define national roles and responsibilities for spent fuel and radioactive waste management. In order to formulate a meaningful policy, it is necessary to have sufficient information on the national situation, for example, on the existing national legal framework, institutional structures, relevant international obligations, other relevant national policies and strategies, indicative waste and spent fuel inventories, the availability of resources, the situation in other countries and the preferences of the major interested parties.

The strategy reflects and elaborates the goals and requirements set out in the policy statement. For its formulation, detailed information is needed on the current situation in the country (organizational, technical and legislative), and on future needs and waste arisings. The technical procedures proposed for the waste types in the country should be politically, technically and economically feasible. When selecting a set of technological procedures, an appropriate end point must be identified, usually a suitable disposal option. The steps in formulating and implementing the strategy include selecting the technological procedures, allocating the responsibility for implementing the identified procedures, establishing supervisory mechanisms and developing implementation plans.

Policies and strategies may need to be updated because of new national circumstances (legislative changes, plans for new nuclear facilities), new international agreements and/or experience obtained with the original policy and strategy. The lead in making changes should be taken by the body

responsible for the initial formulation of the policy (government) and strategy (waste management organization); but all relevant parties in the country should be involved and consulted in this process.

1. INTRODUCTION

1.1. BACKGROUND

Every country should have some form of policy and strategy for managing its spent fuel and radioactive waste. Such policies and strategies are important; they set out the nationally agreed position and plans for managing spent fuel and radioactive waste, and are visible evidence of the concern and intent of the government and the relevant national organizations to ensure that spent fuel and radioactive waste are properly taken care of. Formulation of a national policy and strategy is particularly vital in countries introducing nuclear power; it is one of the prerequisites for initiating such projects.

The words 'policy' and 'strategy' are often used interchangeably. This can be seen both in national reports to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention) [1, 2] and in international documents on the subject. In this publication, a distinction is made; policy is taken to mean the particular goals or requirements for the safe management of spent fuel and radioactive waste management, while strategy is taken to mean the ways and methods used to implement the policy.

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

— Spent fuel management policy;
— Spent fuel management practices;
— Radioactive waste management policy;
— Radioactive waste management practices;
— Criteria used to define and categorize radioactive waste.

National policies and strategies are mentioned in several IAEA publications [3, 4] but the contents of a national policy and strategy are not well elaborated.

There is great diversity in the types and amounts of radioactive waste in different countries and, as a result, the strategies for implementing the policies are sometimes different, although the main elements of policy are likely to be similar between countries.

In some countries, national policies and strategies are well established and documented, while in others they exist but there are no explicit statements

of them and, instead, they have to be inferred from the contents of laws, regulations and guidelines. This is usually because the policy and strategy have been developed gradually over time and incorporated into legislation. The absence of explicit policies and strategies can, however, result in a lack of transparency in relation to the actual policy and strategy on particular aspects and, therefore, where possible, it is desirable to have explicit national policy and strategy statements. Another reason for wishing to have explicit policies and strategies is related to the comparative speed with which political changes can occur in a country, thereby affecting policy and strategy. The content of laws and regulations cannot usually be changed quickly, while the revision of national policy and strategy statements is usually less difficult.

This guide has been prepared to help in developing or upgrading the contents of national policies and strategies for spent fuel and radioactive waste management. An important strategy emphasis in the publication is on the means for reaching appropriate end points in spent fuel and radioactive waste management, such as clearance, discharge and disposal. The guide is intended for use by persons engaged in preparing and drafting national policies and strategies or updating existing ones, and is expected to be of use to all countries that have spent fuel and/or radioactive waste to manage, but in particular to developing countries which have yet to establish their national policies and strategies. In determining the elements of policy and strategy, the guide draws on, among other things, the IAEA Safety Standards and technical reports, and the national reports of Contracting Parties to the review meetings of the Joint Convention [2].

1.2. OBJECTIVE

The objective of this guide is to set out the main elements of national policy and strategy for safe management of radioactive waste and spent fuel declared as waste, recognizing that policies and strategies vary considerably depending on, among other things, the nature and scale of applications of radioactive material in a country. The strategies adopted may also depend on the national availability of waste management competence, facilities and technology. The publication is intended as an aid, resource and reference for those engaged in the development or updating of national policies and strategies for radioactive waste management.

1.3. SCOPE

This guide is only concerned with policies and strategies in the area of radioactive waste management, although many of the principles and concepts discussed here have broader application. It is also relevant for the management of spent fuel declared as waste. The guide is concerned with the contents of policies and strategies, and does not address the development of national laws, regulations and guidelines — although such development is clearly related to the contents of the national policy and strategy. The guide provides an indication of what might be contained in national policies and strategies but does not prescribe what the contents should be, since national policy and strategy have to be decided at the national level, taking into account national priorities and circumstances.

1.4. STRUCTURE

The key definitions used in this guide are set out in Section 2. In Sections 3 and 4, as a background to establishing the content of policies and strategies, the need for them and the principles behind them are described. In Section 5, the prerequisites for the development of a national policy are summarized. Sections 6 and 7 set out the elements to be considered in establishing national policies and the steps to be taken to implement them. The prerequisites for developing a strategy and the technical options for implementing it are described in Sections 8 and 9, respectively. In Section 10, the factors to consider when developing a national strategy are described and in Section 11 the steps to be taken in formulating and implementing the strategy are set out. Section 12 discusses the updating of national policies and strategies. Finally, an annex contains an example of a policy and strategy for a country with a small amount of radioactive waste.

2. DEFINITIONS

For the purpose of this guide, the following definitions are used:

— **Policy** is a set of established goals or requirements for the safe management of spent fuel and radioactive waste; it normally defines national roles and responsibilities. As such, policy is mainly established by

the national government; policy may also be codified in the national legislative system.

— **Strategy** is the means for achieving the goals and requirements set out in the national policy for the safe management of spent fuel and radioactive waste. Strategy is normally established by the relevant waste owner or operator, either a governmental agency or a private entity. The national policy may be elaborated in several different strategies. The individual strategies may address different types of waste (e.g. reactor waste, decommissioning waste, institutional waste, etc.) or waste belonging to different owners.

The line separating policy from strategy is not always sharp and sometimes it is not clear whether an issue should be taken up in terms of a policy or strategy. For example, some policy makers might only place the requirement for the safe management of radioactive waste into policy, and then rely upon strategy makers to decide on the method for achieving this. Other policy makers might include a requirement for a particular management method directly into national policy. Some countries may not distinguish between the two concepts and, instead, have a national plan which is, in fact, a combined policy and strategy.

The links between national policy statements, policy implementation and the establishment of relevant strategies are illustrated in Fig. 1.

3. NEED FOR A SPENT FUEL AND RADIOACTIVE WASTE MANAGEMENT POLICY AND STRATEGY

A policy for spent fuel and radioactive waste management with defined goals and requirements is needed:

— As a basis for the preparation, review or revision of related legislation;
— To define roles and responsibilities for ensuring the safe management of spent fuel and radioactive waste;
— As a starting point for the development of national spent fuel and radioactive waste management programmes (strategies);
— As a starting point for further developments and modifications to existing national practices;

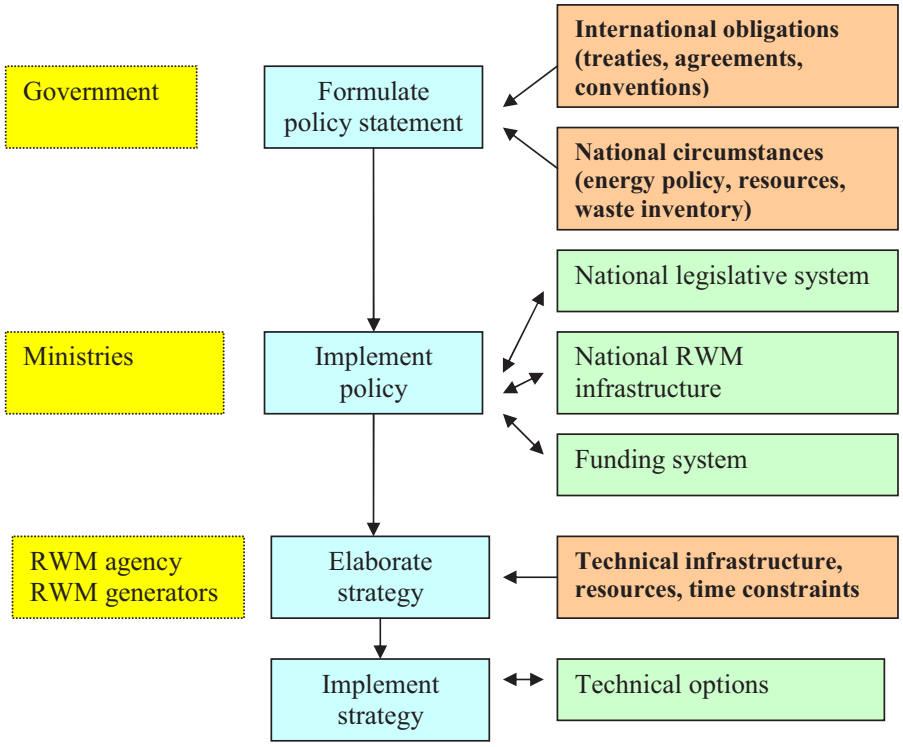

FIG. 1. The principal steps in the development and implementation of a radioactive waste management (RWM) policy and strategy.

— To provide for the safety and sustainability of radioactive waste management over generations, and for the adequate allocation of financial and human resources over time;
— To enhance public confidence in relation to the subject of spent fuel and radioactive waste management.

The set of declared national goals and requirements for the safe management of spent fuel and radioactive waste has to be translated into a more practical and operational form or strategy to provide for their implementation. Strategies are needed to:

— Specify how the national radioactive waste management and spent fuel policy will be implemented by the responsible organizations using the available technical measures and financial resources;

— Define how and when the identified goals and requirements will be achieved;
— Identify the competencies needed for achieving the goals and how they will be provided;
— Elaborate the ways in which the various types of radioactive waste in the country, including, where appropriate, spent fuel, will be managed during all phases of the radioactive waste life cycle (from cradle to grave);
— To enhance public confidence in relation to the subject of spent fuel and radioactive waste management.

A well defined policy and associated strategies are useful in promoting consistency of emphasis and direction within all of the sectors involved in spent fuel and radioactive waste management. The absence of policy and strategy can lead to confusion or lack of coordination and direction.

A policy and/or strategy may sometimes be needed to prevent inaction on a particular waste management issue or to resolve an impasse.

4. PRINCIPLES FOR ESTABLISHING A POLICY AND STRATEGY

According to the IAEA Fundamental Safety Principles [4], the objective of radioactive waste management is to deal with radioactive waste in a manner that protects human health and the environment now and in the future without imposing undue burdens on future generations.

Over the years, a number of principles have emerged which influence the thinking of policy makers in the area of spent fuel and radioactive waste management. Most of these principles are shared globally and some have emerged from the need for countries to interact and co-exist with each other. These principles influence national policy, laws, regulations and guidance as well as radioactive waste management strategy.

In 1996, the IAEA formulated Safety Fundamentals on the Principles of Radioactive Waste Management,[1] which form the technical basis for the Joint Convention [2]. In 2006, they were superseded by a more general high level

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, The Principles of Radioactive Waste Management, Safety Series No. 111F, IAEA, Vienna (1966).

document entitled the Fundamental Safety Principles [5], which sets out principles for the entire nuclear safety area. The principles identified in the 1996 Safety Fundamentals are covered in Ref. [5], but in a more general way, less specific for radioactive waste management. In particular, these principles include:

— *Responsibility for safety:* The prime responsibility for safety must rest with the person or organization responsible for the facilities and activities that give rise to radiation risks;
— *Role of government:* An effective legal and governmental framework for safety, including an independent regulatory body must be established and sustained;
— *Management of safety:* Effective management of safety must be established and sustained in facilities and activities that give rise to radiation risks;
— *Justification of facilities and activities:* Facilities and activities that give rise to radiation risks must yield an overall benefit;
— *Optimization of protection:* Protection must be optimized to provide the highest level of safety that can reasonably be achieved;
— *Limitation of risks to individuals:* Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm;
— *Protection of present and future generations:* People and the environment, present and future, must be protected against radiation risks;
— *Prevention of accidents:* All practical efforts must be made to prevent nuclear or radiation accidents;
— *Emergency preparedness and response:* Arrangements must be made for emergency preparedness and response in case of nuclear or radiation incidents;
— *Protective actions to reduce existing or unregulated radiation risks:* These must be justified and optimized.

Other relevant considerations include:

— *Public participation in decision making:* Decisions which may have a potential health, social or environmental impact should be made in consultation with those who may be affected (the regional Aarhus Convention [6]);

— *Sustainable development:* In view of the long periods of time into the future that radioactive waste and spent fuel may have to be safely managed, sustainability considerations are relevant. There should, therefore, be a focus on meeting the needs of the present without compromising the ability of future generations to meet their own needs [7].

The principles and considerations listed above may not be explicitly present in national policy but they will usually have influenced it as well as the relevant national laws, regulations and guidance that flow from it. They provide a commonly understood basis for guiding all activities related to the safe management of radioactive waste.

5. PREREQUISITES FOR POLICY DEVELOPMENT

As a first step towards developing or updating a policy for spent fuel and radioactive waste, it is necessary for the persons engaged in their preparation to be aware of the existing situation in the country. They should, among other things, have an understanding of the topics listed below.

5.1. PRESENT NATIONAL LEGAL FRAMEWORK

The existing national legal structure and regulatory framework, and their suitability for implementing policies for the safe management of spent fuel and radioactive waste.

5.2. PRESENT INSTITUTIONAL STRUCTURE

The existing institutional structure (regulatory body, radioactive waste management organization and facilities) within the country for the management of radioactive waste and spent fuel.

5.3. APPLICABLE INTERNATIONAL CONVENTIONS

The applicable international instruments and the obligations placed on the country as a result of these instruments. The Joint Convention [1] is clearly relevant here but other conventions, such as the London Convention, 1972 [8] (as related to radioactive waste dumping at sea), the Ospar Convention [9] (as related to the discharge of radioactive material into the north-east Atlantic Ocean) and some others may be relevant for some countries.[2]

5.4. PRESENT NATIONAL POLICIES AND STRATEGIES

The content of existing relevant national policies, if any, in relation to spent fuel and radioactive waste management, and the existence of applicable strategies which would be available in response to any policy development.

5.5. SPENT FUEL AND RADIOACTIVE WASTE INVENTORY

Indicative national inventories (amounts and types) of existing and anticipated spent fuel and radioactive waste.

5.6. AVAILABILITY OF RESOURCES

The scale of the resources (human, financial, technical) available in the country to facilitate implementation of the policy.

5.7. SITUATION IN OTHER COUNTRIES

The waste management solutions being used in the region and the facilities/technologies available in other countries that could potentially be shared.

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[2] Convention on Environmental Impact Assessment in a Transboundary Context, Espoo, Finland, 25 February 1991 and Protocol on Strategic Environmental Assessment, Kiev, 2003; Convention relating to civil liability in the field of maritime carriage of nuclear material, Brussels, 17 December 1971.

5.8. INVOLVEMENT OF INTERESTED PARTIES

The main parties concerned and involved with spent fuel and radioactive waste management in the country.

6. TYPICAL ELEMENTS OF A NATIONAL POLICY

A national policy should reflect national priorities, circumstances, structures, and human and financial resources. It should also be compatible with relevant international instruments and be consistent and coherent with other, non-nuclear policies, in particular, those dealing with other hazardous materials.

The policy adopted may depend, in some respects, on the national political and social system, and this may influence the extent to which the national government is involved in radioactive waste management.

Some of the elements of national policy may be based on the general principles summarized in Section 4. Others may be specific to the circumstances of the country, for example, a policy on the return of disused sealed sources to the supplier, or on the export and import of radioactive waste.

The national policy may be influenced by a number of factors, such as the amount, type and the characteristics of the radioactive waste, and the geographical distribution of the radioactive waste and of the population. Both existing and future, planned or anticipated developments in the field need to be considered.

The national policy for radioactive waste management should reflect the magnitude and scale of the hazard posed by the waste (a graded approach). While countries having radioactive waste from a large nuclear industry, which might include uranium mining and milling, nuclear fuel production and reprocessing, and nuclear power generation, as well as the institutional use of radioisotopes, may require an elaborate and comprehensive policy for the management of their radioactive waste, for countries without a nuclear power programme and only a few sources of radioactive waste, a simpler policy with only a few elements may be adequate.

The national policy for spent fuel and radioactive waste management may need to be updated to improve parts of the policy based on experience of its application and to reflect the changing circumstances in the country and in the world; national authorities may have a review mechanism in place for this purpose.

Some of the main elements to be considered in establishing a national policy for spent fuel radioactive waste management are discussed below. Not all of these points may be relevant to all countries and, therefore, some selection may be necessary in developing a policy for a particular country. Equally, other items, not included here, may be important for the policy of a particular country.

6.1. ALLOCATION OF RESPONSIBILITIES

In most countries, it is accepted that the person or organization that creates the waste is responsible for it and for its safe management;[3] however, national governments also have responsibilities in this context.[4]

In addition, governments should provide for control over sources of radiation for which no other organization has responsibility, such as radioactive residues from past facilities and activities, and orphan sources.[5]

Governments should establish a legislative and regulatory framework, including the designation of an independent regulatory body to enforce, among other things, the regulations for the safe management of spent fuel and radioactive waste (Articles 19 and 20 of the Joint Convention [2]). Governments should also ensure that arrangements are implemented for the safe long term management of radioactive waste.

It is important for there to be clarity concerning national responsibilities for managing spent fuel and radioactive waste. Thus, the national policy should identify:

— The government organization(s) responsible for establishing the legislative and regulatory framework;
— The relevant regulatory body;

[3] Article 21.1. of the Joint Convention [1] reads: "Each Contracting Party shall ensure that prime responsibility for the safety of spent fuel or radioactive waste management rests with the holder of the relevant license and shall take the appropriate steps to ensure that each such license holder meets its responsibility."

[4] Paragraph (vi) of the Preamble to the Joint Convention [1] reads: "Reaffirming that the ultimate responsibility for ensuring the safety of spent fuel and radioactive waste management rest with the State."

[5] Article 21.2. of the Joint Convention [1] reads: "If there is no such licence holder or other responsible party, the responsibility rests with the Contracting Party which has jurisdiction over the spent fuel or over the radioactive waste."

— The organization(s) responsible for ensuring that radioactive waste is safely managed (normally the licencee);
— The organization(s) responsible for the long term management of spent fuel and radioactive waste, and for radioactive waste for which no other organization has responsibility.

6.2. PROVISION OF RESOURCES

The waste owner is generally considered to be financially responsible for ensuring that radioactive waste is properly and safely managed, i.e. in accordance with the 'polluter pays' principle [10]. However, the arrangements for the long term management of radioactive waste are normally coordinated or overseen at the national level. In this context, Article 22 of the Joint Convention [2] requires that:

"Each Contracting Party shall take the appropriate steps to ensure that:

(i) qualified staff are available as needed for safety-related activities during the operating lifetime of a spent fuel and a radioactive waste management facility;
(ii) adequate financial resources are available to support the safety of facilities for spent fuel and radioactive waste management during their operating lifetime and for decommissioning;
(iii) financial provision is made which will enable the appropriate institutional controls and monitoring arrangements to be continued for the period deemed necessary following the closure of a disposal facility."

Thus, the national policy should set out the arrangements for:

— Establishing the mechanisms for providing the resources or funds for the safe, long term management of spent fuel and radioactive waste;
— Ensuring that there are adequate human resources available to provide for the safe management of spent fuel and radioactive waste, including, as necessary, resources for training and R&D;
— Providing institutional controls and monitoring arrangements to ensure the safety of spent fuel and radioactive waste storage facilities and waste repositories during operation and after closure.

This is discussed in detail in Ref. [11].

6.3. SAFETY AND SECURITY OBJECTIVES

A common overarching element in national policy on spent fuel and radioactive waste management is the safety objective. This can be stated as being: to protect individuals, society and the environment from the harmful effects of ionizing radiation due to spent fuel and radioactive waste both now and in the future (Article 1 (ii) of the Joint Convention [2] and Ref. [5]). In addition, the policy should require, where appropriate, that there is physical protection and security of facilities in order to prevent the unauthorized access of individuals and the unauthorized removal of radioactive material [12].

6.4. WASTE MINIMIZATION

The national policy may address the need to minimize the generation of radioactive waste at the design (minimization at source), operation and decommissioning stages of facilities (see Article 4 (ii) of the Joint Convention [2]). In this regard, it may identify some of the main means for achieving waste minimization in the operational and decommissioning stages of facilities, including:

— The recycling and reuse of materials which are free of contamination or only slightly contaminated;
— The use of the clearance concept for determining the materials that can be released safely from regulatory control [12, 13].

6.5. EXPORT/IMPORT OF RADIOACTIVE WASTE

In some countries, there is concern that the national facilities developed for the storage and/or disposal of radioactive waste of national origin might be used for the waste of other countries and, for this reason, their national policies contain an explicit statement excluding this possibility. On the other hand, some countries are seeking international solutions for the long term management of radioactive waste and for this approach to succeed, the possibility of exporting and importing radioactive waste must exist among the countries choosing this option (paragraph (xi) of the Preamble to the Joint Convention [2]).

The requirements for ensuring the safety of such operations are specified in Articles 27 and 28 of the Joint Convention [2].

The national policy may, thus, specify:

— Conditions on the import and/or export of radioactive waste;
— An intention to store/dispose of radioactive waste on national territory;
— An intention to seek international/regional solutions.

6.6. MANAGEMENT OF SPENT FUEL

The national policy on the management of spent fuel should be made clear (Preamble of the Joint Convention [2]). The policy may, for example:

— Consider the spent fuel as a resource and seek to utilize the resource through reprocessing (nationally or internationally);
— Regard spent fuel as a waste and specify that it be disposed of directly;
— State that spent fuel be returned to the supplier.

In many countries, spent fuel is stored on an interim basis while waiting for either of the first two options to be decided upon. In the case of spent fuel from research reactors, the last option has often been adopted.

Spent fuel is a subject of nuclear safeguard controls and this aspect needs to be appropriately addressed when developing national policy [14].

6.7. MANAGEMENT OF RADIOACTIVE WASTE

6.7.1. Disused sealed radioactive sources

Although disused sealed radioactive sources are only one component of the national radioactive waste inventory, they are particularly important for some countries with little other hazardous radioactive waste to manage. For this reason, the policy for their management may be specified in the national policy. Measures to be addressed at the policy document level are specified in Article 28 of the Joint Convention [2]. Safety requirements for disused sealed sources are presented in Refs [3, 12, 15, 16].

The management options for disused sealed sources may include:

— Return of the disused sealed radioactive sources to the supplier;
— Management of the sources on national territory;
— International radioactive waste management solutions.

6.7.2. Other types of radioactive waste

The national policy should identify the main sources of radioactive waste in the country, including the decommissioning of facilities, if appropriate, and should:

— Identify the intended national arrangements for the management of the main types of radioactive waste;
— Identify the end points of the management process;
— Recognize that some radioactive waste may be potentially hazardous for long into the future and, therefore, require long term safety measures.

6.8. NATURALLY OCCURRING RADIOACTIVE MATERIAL

Naturally occurring radioactive material (NORM) arises from various industries as a by-product, residue or waste; management approaches vary in different countries. In some countries, NORM is regarded as being subject to regulation by the nuclear regulatory authority, while in others it falls within the responsibility of non-radioactive regulators; however, its radioactive properties are taken into consideration in both cases. For this reason, it is important that national policy should indicate the regulatory regime under which NORM is managed (Article 3.2 of the Joint Convention [2]).

Tailings from uranium mining and milling may also be included in this category.

6.9. PUBLIC INFORMATION AND PARTICIPATION

The national policy may indicate the State's intention to inform the public about proposed plans for radioactive waste management, and to consult concerned parties and members of the public to aid in making related decisions (Paragraph (iv) of the Preamble of the Joint Convention [2] and Ref. [17]). Nowadays, governments tend to emphasize their commitment to policies of openness and transparency in relation to their intentions and plans on radioactive waste management.

7. ESTABLISHMENT AND IMPLEMENTATION OF A NATIONAL POLICY

7.1. CREATING A NATIONAL POLICY STATEMENT

A national policy statement must represent the views of all of the organizations concerned in the management of spent fuel and radioactive waste. An appropriate representative committee should, therefore, be established to develop the policy or to update existing policy. The committee should contain representatives of the regulatory body, the radioactive waste management organization, the radioactive waste generators and other organizations with responsibilities in the area of radioactive waste management. The process for developing policy should take account of all the topics listed in Section 6 and of any others which are specific to the country. If a policy is being updated, account should be taken of all relevant national and international changes and events that have occurred since the previous policy was developed. The draft policy document should be reviewed by all relevant national organizations. After this, approval of the policy statement by government should be sought through appropriate channels; it is recognized that these will differ from country to country. The aim is to produce a policy statement which reflects the official position of the government on spent fuel and radioactive waste management.

The incorporation of national policy into the relevant legislation adds formalization and is a desirable outcome of the policy updating process. However, this may not be necessary if it is clearly understood that the policy statement represents the government's position on the subject and provided that it does not cause any conflicts with existing legislation.

7.2. IMPLEMENTING THE POLICY

A process for the implementation of a national policy is given in Fig. 1.

Implementation of the policy requires that there is an adequate and appropriate waste management institutional framework in the country. If this does not exist, the initial implementation step should be to establish such a framework. This framework should include two basic bodies: an organization, or organizations, devoted to coordinating or overseeing radioactive waste management, and an independent regulatory body established to enforce the implementation of the regulations on spent fuel and radioactive waste management. Other governmental bodies may have roles in the process, for

example, government organizations concerned with environmental protection and the transport of radioactive material as well as local governmental organizations. Responsibilities for implementing the various aspects of national policy should be allocated within the relevant organizations.

The competence of the staff of the radioactive waste management organizations and the regulatory body should be adequate for the work to be performed and training should be provided to ensure that the organizations achieve and maintain competence.

There should be a funding mechanism to provide adequate financial resources for the management of spent fuel and radioactive waste, both in the short and longer term. This will often involve contributions being made to a central fund by the organizations in the country that generate radioactive waste. In other cases, central government may take partial or full financial responsibility for radioactive waste management. The funds should be used to provide the necessary facilities and equipment for safe radioactive waste and spent fuel management, and the staff to operate them.

8. PREREQUISITES FOR STRATEGY DEVELOPMENT

The national strategy for managing spent fuel and radioactive waste should be derived from the national policy, as indicated in Fig. 1.

In order to develop or update a national strategy or the strategy of one of the implementing organizations, the persons involved should, among other things, have an understanding of the topics listed below.

8.1. INVENTORY OF SPENT FUEL AND RADIOACTIVE WASTE

Estimates of the amounts and types of existing and future spent fuel and radioactive waste in the country.

8.2. WASTE CLASSIFICATION

The national classification scheme for radioactive waste.

8.3. WASTE CHARACTERIZATION

The radiochemical and physical characteristics of the radioactive waste, the owners and locations of the spent fuel and radioactive waste.

8.4. WASTE MANAGEMENT STRATEGIES IN OTHER COUNTRIES

The strategies being used for managing similar waste types in other countries.

8.5. EXISTING WASTE MANAGEMENT FACILITIES

Knowledge of existing and planned facilities for radioactive waste and spent fuel management in the country.

8.6. AVAILABILITY OF RESOURCES

Details of the funds and available expertise to support spent fuel and radioactive waste management activities in the country.

8.7. EXISTING REGULATORY REGIME

The existing regulatory regime related to the safe management of spent fuel and radioactive waste.

8.8. CONCERNED PARTIES' EXPECTATIONS AND INTERESTS

The expectations and interests of the main parties concerned and involved with spent fuel and radioactive waste management in the country.

9. STRATEGY DEVELOPMENT — AVAILABLE OPTIONS

Many countries rely on a national waste management strategy (in some countries called a 'national plan') to guide the management of their radioactive waste. These strategies are formulated from a national perspective and often specify one administrative entity, the radioactive waste management organization, as responsible for coordinating the development of such plans. The waste management organization is usually the operator of radioactive waste disposal facilities, but may also serve other waste management and decommissioning roles.

Some countries may prefer formulating strategy in two levels: principal matters are prescribed in general terms as a national strategy by government and its detailed implementation is delegated to particular waste owners (company strategies). This approach can be recommended to improve coordination of waste management, increase its safety and security, and to efficiently exploit national resources. Typically, a single national repository may be planned instead of several facilities owned by large waste generators; centralized waste treatment and conditioning services may be created for small waste generators; or management of spent fuel owned by different entities may be centrally coordinated.

In some cases, countries may choose to only establish a strategy for a particular type of radioactive waste (e.g. for the long term management of spent fuel and high level waste). For reasons of legal jurisdiction, national policy or as a matter of preference, some countries may prefer not to create a national strategy for radioactive waste management. Finally, in some countries, to have or not to have a radioactive management strategy is a decision that is left to individual waste generators.

Approaches for establishing waste management strategies in the Member States may vary according to their needs and preferences. Whatever is selected from among the above options should be codified by a responsible supervising national body.

9.1. GENERAL ASPECTS

A general aim in the management of radioactive waste is to reduce, to as low as practicable and justifiable, the associated risks by appropriate processing, containment and eventual disposal. Reducing the volume of the waste minimizes the requirements on the waste management system and reduces the associated costs. Waste volume reduction may be achieved through

the optimization of nuclear facility design, including the appropriate choice of materials, the application of good operational practices and the recycling and reuse of materials [18].

The volumes of radioactive waste for storage and disposal may also be reduced if parts which are sufficiently low in activity concentration to satisfy the regulatory requirements for exemption/clearance can be identified [12, 13]. These materials may be separated and treated as non-radioactive materials, that is, reused, recycled or disposed of as normal waste. Further volume reduction can be achieved by segregating waste containing only very short lived radionuclides from other types of waste. This waste can be stored to allow decay to below levels that allow exemption/clearance from control. For this reason, radioactive waste should be characterized in relation to its physical, chemical and radiological properties. The segregation of radioactive waste according to radiological, chemical and physical properties may also facilitate its handling and processing [19].

The generally preferred approach for the management of radioactive waste is to concentrate the waste and to contain the radionuclides in it by means of a waste matrix and waste container followed by disposal in an appropriate disposal facility designed to provide isolation from the biosphere. For radioactive waste in liquid and gaseous forms, however, it may be appropriate to release them into the environment provided that their concentrations are sufficiently low to satisfy the requirements set by the national regulatory body. Otherwise, they must also be concentrated and contained after appropriate processing and managed as solid waste.

When the concentrate/contain approach is selected, the following steps are normally taken, although not all are needed for the different waste types:

— *Waste collection, characterization and segregation:* For the purpose of determining the waste properties and suitably grouping and separating waste types, if applicable, for further processing;
— *Waste treatment:* For the purpose of easing conditioning operations through volume reduction, removal of radionuclides from the waste and change of physical and/or chemical composition;
— *Waste conditioning:* For the purpose of producing packaged waste suitable for handling, transport, storage and disposal; it is achieved through the processes of solidification, embedding and/or encapsulation;
— *Storage:* To hold the waste during its processing (buffer storage), to hold unconditioned waste until it reaches clearance levels (decay storage), to temporarily hold waste prior to its transport to a disposal facility or to hold waste until a final waste repository becomes available.

The final step is waste disposal, which is intended to remove or isolate the waste from the biosphere in order to prevent it causing harm to humans or the environment.

Waste management strategies and the range of technical options for managing spent fuel and the various types of radioactive waste are discussed in the following paragraphs with respect to a newly proposed IAEA waste classification scheme (Fig. 2). An overview of the possible technical options for managing radioactive waste is given in Table 1 of Annex II.

9.2. VERY SHORT LIVED WASTE

Storage for decay is normally considered for waste that can be released from regulatory control within a period of a few years, exceptionally tens of years. This waste is termed very short lived waste (VSLW). It contains mostly radionuclides of very short half-life (typically <100 d, but exceptionally several years). The activity concentration of this waste falls below clearance levels within the storage times mentioned above. Radioactive waste of this type is

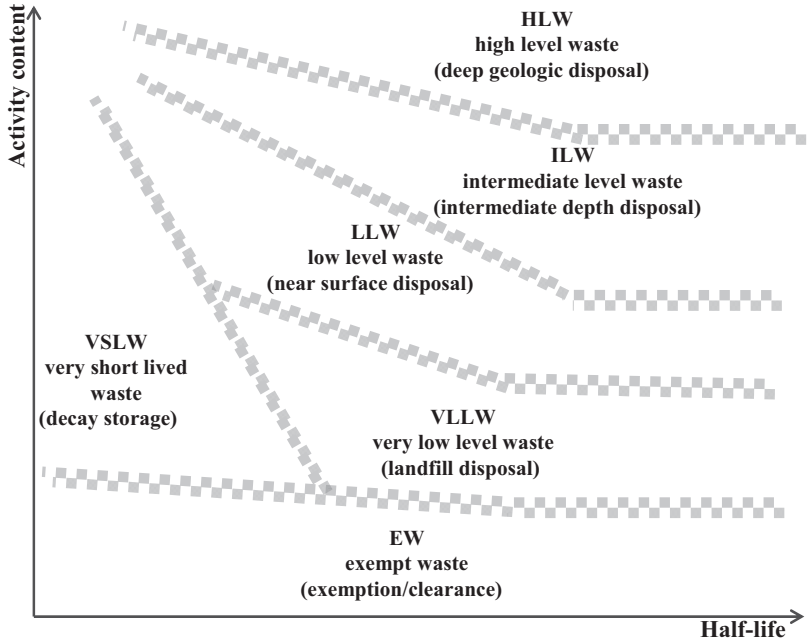

FIG. 2. Proposed new radioactive waste classification scheme [20].

typically produced from radionuclide applications for research and medical purposes [21].

9.3. VERY LOW LEVEL WASTE

Very low level waste (VLLW) is waste that is low in activity concentration but contains some longer lived radionuclides. It does not require a high level of containment although radiation protection provisions are needed while the waste is being processed. Its activity concentration does not usually exceed one hundred times clearance levels for each of the radionuclides concerned. For convenience, waste with activity concentrations in the region of, or below, clearance levels is sometimes processed together with VLLW.

VLLW often exists in large volumes. It is mainly generated during the operational, decommissioning and dismantling stages of a nuclear facility. Typical VLLW includes concrete, soil and rubble.

9.3.1. Processing of VLLW

The volume of potential VLLW can be reduced by appropriate characterization to separate those components that may be released as cleared waste.

9.3.2. Storage of VLLW

Generally, VLLW is stored at the site of its generation until transport to a suitable disposal facility. During this stage, a simple shelter or temporary cover may be appropriate to provide protection from atmospheric influences (precipitation, wind).

9.3.3. Disposal of VLLW

In some countries, VLLW is disposed of in purpose-built disposal facilities, in the form of earthen trenches with engineered covers. In other countries, it is disposed of with other waste types, e.g. low level waste (LLW). The decision on disposal method is usually made on economic and/or regulatory grounds [22].

9.4. LOW LEVEL WASTE

LLW contains higher activity concentrations than VLLW but with a limit on the concentration of long lived radionuclides, i.e. radionuclides with $T_{1/2} > 30$ years. It requires isolation from the biosphere for periods of up to a few hundred years [22, 23]. It is common practice to dispose of LLW in engineered near surface facilities. LLW is generated in most facilities involved in nuclear power production, nuclear research and nuclear medicine.

9.4.1. Processing of LLW

The processing of LLW consists of treatment and conditioning to prepare for transport, storage and disposal. The treatment and conditioning options chosen are determined taking into account the planned storage and/or disposal method used [24].

9.4.2. Treatment of solid waste

In the treatment of solid waste:

— Compaction is aimed at reducing the volume and increasing the stability of solid waste for transport, storage and disposal. The volume reduction achievable depends on the nature of the waste and the equipment used; reduction factors of about three to eight are achievable;
— Incineration can be applied to both solid and liquid combustible LLW; it achieves the highest volume reduction as well as yielding a chemically stable form. The facility used for incineration should be designed to retain the radionuclides during the incineration process and must be approved by the regulatory body. After combustion, radionuclides from the waste are distributed between ash, the product from the cleaning of the exhaust gases and airborne particles contained in washing liquids, spent filters and stack discharges. All these secondary wastes need further conditioning before disposal;
— The melting of metallic (and sometimes polymeric) waste may bring high volume reduction. The resulting waste form is compact (ingots, polymer blocks) and does not usually require packaging. However, secondary waste is also created (slag, filters).

9.4.3. Treatment of liquid LLW

The treatment processes for liquid LLW are directed towards volume reduction and the removal of radionuclides from the bulk of the waste. They result in a concentrated waste stream (that has to be further conditioned) and a supernatant/distillate which can often be cleared from regulatory control and directly released or released after additional treatment. The most common methods are:

— *Chemical:* Precipitation using chemicals such as barium chloride, sodium sulphate, potassium ferrocyanide, copper sulphate, etc. The resultant sludge that contains the bulk of radioactivity requires conditioning;
— *Evaporation:* Evaporation of aqueous or organic solutions concentrates radionuclides and results in a very high waste volume reduction factor as well as a high decontamination factor. The resulting concentrate must be further conditioned;
— *Ion exchange:* Extraction by selective ion exchange resins, both organic and inorganic. The spent resin must be subsequently conditioned;
— *Membrane methods:* Processes such as reverse and electro-osmosis, nano and ultrafiltration in combination with other treatment methods (chemical treatment or ion exchange processes) can be employed to further improve the decontamination of waste liquids. The used membranes and the concentrates must be further conditioned.

9.4.4. Conditioning

Conditioning produces a more stable physical or chemical form. Cementation and bituminization are the most typical solidification technologies used for liquid LLW. Processed or unprocessed LLW may also be placed into high integrity containers capable of providing containment for long periods of time. Steel, plastic (high density polyethylene) or concrete containers have been developed for this purpose.

9.4.5. Storage of LLW

The objective of this type of storage is to contain the waste until it can be sent for disposal (or as a buffer stage between processing steps) [25]. Waste packages should be housed within a suitable storage structure that provides a sheltered, non-corrosive environment and is physically secure.

9.4.6. Disposal of LLW

Options for the disposal of LLW include [26]:

— Near surface disposal facilities: These are in the form of simple or engineered trenches or concrete vaults in which containerized waste is placed. An engineered or earthen cap is placed over the waste containers to minimize water infiltration. The facilities are subject to surveillance until the hazard associated with the waste has declined to acceptable levels;
— Subsurface disposal facilities: Some countries prefer disposing of LLW in subsurface facilities or co-locating LLW with intermediate level waste (ILW) or spent fuel in deeper facilities.

9.5. INTERMEDIATE LEVEL WASTE

ILW has a higher concentration of radionuclides, especially long lived radionuclides, than LLW; it may require shielding to provide adequate protection for workers and greater provisions ensure its isolation from the biosphere. However, ILW needs no or only limited provision for heat dissipation during its storage and disposal. To provide for long term safety, disposal at greater depths than for LLW is normally considered to be appropriate (at least several tens of metres).

ILW typically comprises metals which have been irradiated in reactor cores, graphite waste, ion exchange resins and fuel cladding waste resulting from spent fuel reprocessing.

9.5.1. Processing of ILW

In principle, all methods used for LLW are also acceptable for ILW. An important factor to be considered in choosing the processing option is the radiation resistance required of the waste form.

9.5.2. Storage of ILW

Options for storage of ILW are similar to those for LLW. Additional shielding may be required to limit radiation dose rates near ILW containers.

9.5.3. Disposal of ILW

Disposal at depths of greater than several tens of metres is generally considered to be the most appropriate option for ILW. While repositories specifically for ILW exist in some countries, in others, co-disposal with spent fuel and high level waste (HLW) is being considered.

9.6. SPENT FUEL AND HLW

The waste management strategy for spent fuel and HLW is affected by the nuclear fuel cycle policies adopted by a State. Two distinct nuclear fuel cycles are employed (recognizing that some Member States have postponed the decision on which approach to adopt and are taking the 'wait and see' approach):

— Open fuel cycle: Spent fuel is considered to be HLW;
— Closed fuel cycle: Spent fuel is reprocessed to recover unused uranium and the plutonium generated by nuclear fission, with the production of HLW.

Spent fuel and HLW are highly radioactive and heat generating, and need to be cooled and shielded.

9.6.1. Processing of HLW

Prior to processing, liquid HLW is stored in cooled high integrity double walled stainless steel tanks housed in special vaults. Processing of liquid HLW involves chemical treatment and evaporation followed by vitrification using borosilicate or phosphate glasses, or incorporation in ceramic compositions. The solid product is contained in stainless steel canisters.

9.6.2. Storage of spent fuel and HLW

After removal from a reactor, spent fuel requires shielding and heat removal. These functions are provided by water in storage pools built at the reactor. After several years of cooling, the fuel is transferred to a separate storage facility, either wet (pools) or dry (vaults or casks). The eventual need to retrieve and transport the spent fuel to a disposal facility or for reprocessing has to be considered when designing the storage facilities [27].

The final product of HLW conditioning is a canister containing most of the radioactive material from reprocessing immobilized in a glass or ceramic matrix. HLW canisters are stored in air cooled vaults (similar in construction to spent fuel storage vaults).

Spent fuel and HLW are stored until disposal facilities become available.

9.6.3. Disposal of spent fuel and HLW

Disposal in deep geological repositories is generally considered to be the best way to provide a permanent management solution for spent fuel and HLW [28]. While most countries with spent fuel and HLW are working towards national solutions, others, for mainly economic reasons, have indicated an interest in developing multinational disposal facilities [29].

9.7. DISUSED SEALED RADIOACTIVE SOURCES

The preferred option for the management of disused sealed radioactive sources is to return them to their supplier for reuse or disposal. Sometimes this is not possible, especially for older sources where the supplier is not known or is no longer in business. Alternative solutions are, therefore, necessary.

9.7.1. Processing of disused, sealed radioactive sources

Methods for disused sealed radioactive source processing include metal matrix immobilization (for highly active sealed radiation sources) and encapsulation in stainless steel casings [30, 31]. They may further be grouted in steel drums or other suitable overpack.

9.7.2. Storage of disused sealed radioactive sources

Disused sealed radioactive sources containing short lived radionuclides may be stored for decay in an appropriate container or package and then be released from control (cleared) when their radioactive contents have decayed sufficiently [32, 33].

Capsules containing conditioned disused sealed radioactive sources are stored in an appropriately designed shielded container until appropriate disposal arrangements are available. Provisions to ensure physical security are necessary for some types of high activity source stores [31].

9.7.3. Disposal of disused sealed radioactive sources

Disposal options for disused sealed radioactive sources vary depending on the activity levels and types of radionuclides in the sources [34]. Near surface repositories may be suitable for low activity, short lived sources. For long lived disused sources with activity levels exceeding the criteria for disposal in a near surface repository, underground disposal is the preferred option. For countries without the prospect of such repositories, the possible development of multinational geological repositories in the future would be of interest. Another possibility is the development, on national territory, of a special type of borehole disposal facility intended specifically for the disposal of disused sealed radioactive sources [34].

9.8. NORM

NORM occurs as a by-product, residue or waste from activities such as uranium mining and milling; coal burning; oil and gas extraction; tin, iron, niobium and non-metal mining; and milling and water treatment. NORM contains radionuclides of the uranium and thorium decay chains and is characterized by very large volumes. NORM often contains other toxic substances such as heavy metals and, for this reason, both radiological and non-radiological aspects have to be taken into account for its management. In some countries, NORM is regulated as a radioactive waste and in others as a chemically toxic waste.

9.8.1. Processing of NORM

Processing consists of pile stabilization by various processes in order to increase the safety of storage and disposal sites. Solid, large pieces of NORM waste, such as pipes from the oil industry, are fragmented for handling and transport purposes. Liquid NORM waste is treated to reduce its radionuclide content and mobility. Decontamination and recycling may be effective options for reducing the volume of this waste [35, 36].

9.8.2. Disposal of NORM

NORM waste is generally deposited in consolidated and over-covered piles or sludge beds, or purpose designed repositories with lined cells and protective capping [37]. As it is not feasible to move such large amounts of material, the waste tends to be disposed of on the site of its generation.

Capping and some engineered structures may be used to prevent erosion and to limit the leakage of radioactive gases. In some cases, the waste has been disposed of by using it to backfill disused underground mines.

10. CONSIDERATIONS IN DEVELOPING A STRATEGY

The ultimate objective of radioactive waste management is to protect individuals, society and the environment from the harmful effects of ionizing radiation due to spent fuel and radioactive waste, both now and in the future [2]. The selection of appropriate technologies is a key element in the realization of such an objective. More than one technical option may be available for managing a particular category of radioactive waste, and the appropriate selection and optimization of the available technical systems can be important in terms of economics, efficiency and safety.

The selection of a technical option should also take account of other non-technical factors such as the need to comply with national policies, the availability of financial and human resources, and public sensitivities.

When formulating the strategy, consideration should be given to the timing of the various steps. Facilities should be commissioned in time to provide the required capacity. This requires proper planning and the strategy implementation plan should, therefore, clearly define milestones for technical activities consistent with the anticipated waste generation.

10.1. STRATEGIC APPROACHES

The final destination of the radioactive waste will often influence the waste management strategy to be followed:

Waste recycling, after regulatory clearance, is a preferred option for some materials, especially those containing significant amounts of metal.

Immediate disposal is usually the preferred option but requires that all facilities for predisposal and disposal are available.

Deferred disposal is often the strategy that is adopted, usually because facilities for predisposal or disposal are unavailable. However, other reasons are: (i) to allow waste to accumulate so that it can be processed effectively and economically, (ii) because of a national preference for surface storage (sometimes pending a final decision on its ultimate disposition) and (iii) to decrease thermal output of HLW packages.

A multinational solution, which usually means that the waste is stored on national territory awaiting the development of a suitable international facility.

The choice of an appropriate final destination should precede the formulation of a radioactive waste management strategy since it may influence the waste processing methods to be adopted.

10.2. COMPLIANCE WITH POLICY

The strategy for managing spent fuel and radioactive waste must be developed taking relevant national policies into account. The general issues to be considered are discussed in Section 6. From this, it can be seen that there are some country specific policies that directly affect the development of strategy. Policies that will affect strategy include:

— National policy on the recycling and reuse of materials;
— National policy on the clearance of materials from regulatory control;
— National policy on environmental protection (in some countries, certain disposal options are not allowed, e.g. surface disposal of radioactive waste);
— National policy on the export/import of radioactive waste, e.g. conditions on the import and/or export of radioactive waste; an intention to store/dispose of radioactive waste on national territory; and/or an intention to seek international/regional solutions;
— National policy on the management of spent fuel, e.g. whether spent fuel is considered as a resource (with the application of reprocessing — nationally or internationally), a waste (with the intent to dispose of it as a waste) or whether it is intended to return spent fuel to the supplier;
— National policy on the management of disused sealed radioactive sources, e.g. return of the disused sealed radioactive sources to the supplier; management of the sources on national territory; or international radioactive waste management solutions;

— National policy on the management of NORM, i.e. whether NORM is regulated as a radioactive material or as a chemically toxic material;
— National policy on public information and involvement, e.g. the State's position on informing and consulting the public about proposed plans for radioactive waste management.

There may be other national policies that could influence strategy development in relation to radioactive waste management and there may be international or bilateral agreements with countries that relate to the management of radioactive waste. Some national policies may relate to other issues not directly in the nuclear sphere but which have implications for radioactive waste management; such issues include those concerned with environmental protection, conservation, etc.

10.3. GRADED APPROACH

The nature and scale of the radioactive waste management facilities needed in a country depend on the types and amounts of waste, and the rate at which it is generated. Thus, consideration of these factors is important in determining the most appropriate technical options for waste management.

Radioactive waste management programmes range from being very simple — for countries with few sources of radioactive waste, e.g. disused sealed radioactive sources and some waste from medical applications of radionuclides — to complex — for countries with waste from a full nuclear fuel cycle, and research, medical and industrial applications of radionuclides. Thus, a graded approach is necessary in establishing waste management programmes to suit the varying needs of countries. For many countries, only a few of the options listed in Section 9 will be needed.

10.4. RESOURCES

Radioactive waste management programmes cannot be established and implemented without adequate resources. In this context, 'resources' means financial, human and technical resources. With knowledge of the nature and amounts of radioactive waste in the country, an appropriate strategy for its management can be developed. However, the successful implementation of the strategy requires that there are adequate resources in due time and consideration must, therefore, be given to this aspect at an early stage.

10.4.1. Financial resources

The arrangements for providing the necessary finance for managing radioactive waste are country specific and range from funding systems based on fees charged to waste producers to funds provided directly by the government [38]. However, because of the long term nature of the commitment to managing radioactive waste safely, the government inevitably has to be involved, to some extent, in the long term. Depending upon the nature of the nuclear activities in a country, financial arrangements are required for decommissioning activities, the predisposal and the disposal of radioactive waste.

In countries with nuclear energy production, the fees for radioactive waste management can be added to the price of electricity. Where there is not such a direct link between benefit and cost, the funds may be more difficult to collect. In an extreme situation, the charging of fees for the collection and management of radioactive waste can have the effect of causing small scale waste producers to avoid charges by non-declaration of the waste or by disposing of it illegally.

Prior to implementing a strategy for managing radioactive waste, these aspects must be considered and a suitable financing scheme arrived at. Inadequate financing should not be allowed to compromise safety and the selection of appropriate technical options. However, if it proves not to be possible for the national organization responsible for radioactive waste management to raise the level of funds needed to finance the strategy that has been decided upon, or if the funds are not immediately available, then it may be necessary to develop an alternative interim strategy. Within this interim strategy, it may not be possible to implement all aspects of the original strategy because of financial restraints and priorities must, therefore, be set and actions taken within the financial restraints to ensure that the risk to the public is minimized. An example might be the use of temporary, but safe, storage instead of a purpose built storage facility or a disposal facility.

The long term nature of the funding required for radioactive waste management has to be recognized and provisions should be made for it in the national fund. Alternatively, a commitment to be responsible for the long term management of radioactive waste, e.g. for the long term surveillance and security of radioactive waste repositories, should be made by the government.

10.4.2. Human resources

A properly trained and competent workforce is needed to operate the waste management facilities. Similarly, the facilities must be properly regulated

and the regulatory body must, therefore, be staffed with effective and knowledgeable staff. These are important aspects to be considered in developing or updating a national strategy.

An assessment should be made of the number of staff needed and the levels of competence needed for the implementation of the technical options decided upon. Based on such an assessment, the adequacy of the existing staff for this purpose should be determined. If improvements are needed in the levels of competence of existing staff or if the numbers are insufficient, arrangements including training of existing staff and/or staff recruitment should be made to remedy this. Staff recruitment and training should be planned and implemented prior to the installation of new equipment and facilities. Planning should also provide for the supply of new staff members to replace those who retire or change jobs.

10.4.3. Technical resources

As part of the strategy development, the existing technical resources in the country should be reviewed. This includes existing management facilities and the transport arrangements for waste. It also includes the national organizations responsible for managing and regulating radioactive waste.

The adequacy of the existing facilities and their capacity for incorporating any newly planned technical elements should be assessed; this should include the existing waste management handling, processing, storage and disposal arrangements. This review may point to the need to upgrade facilities and equipment or to develop new ones. Detailed provisions for upgrading existing facilities and equipment or constructing new facilities can then be included in the strategy. The review may also point to the need for new or improved roads and/or railways to facilitate the safe transport of radioactive waste.

These considerations may have important implications for funding. In this context, it is noted that the costs of upgrading are usually less than those for establishing new facilities.

The adequacy of national organizations for managing radioactive waste and for regulating the planned waste management activities should also be assessed and, if necessary, plans for their improvement should be included in the national strategy. In assessing adequacy, the assessment should review past national experience in the management of radioactive waste. It may also consider the infrastructure existing in other countries for radioactive waste management.

Strategy development should also address the possible need for national R&D in this area. This depends, to a large extent, upon the level of technology required in the country for radioactive waste management. Countries with

nuclear power generating facilities are likely to need an R&D capacity to support the development of waste management technology. However, a graded approach should be applied and specific R&D capacity is unlikely to be relevant to countries with only small amounts of institutional waste to manage. These countries may be better advised to call upon the expertise of countries with developed nuclear programmes.

10.5. GENERIC TECHNICAL OPTIONS

The technical options appropriate to different types of radioactive waste are summarized in Section 9. However, in addition, there are some more general technical approaches that countries may consider for the management of their waste. These include the sharing of facilities, the centralization of facilities and the use of mobile processing facilities.

10.5.1. Shared facilities

Countries may consider sharing dedicated radioactive waste management facilities with other countries. This approach has the benefit of decreasing the cost of waste management for all countries involved. It is regularly applied for melting and incineration of LLW.

Shared facilities could include multilateral facilities for storage and disposal. Such proposals have been made in the framework of the Joint Convention related to the multilateral storage of spent fuel (see report of the Second Review Meeting [1]) and discussions have taken place between interested countries [29].

Another type of international sharing has occurred in relation to the reprocessing of spent fuel. Some countries with developed fuel cycle capacities have provided commercial reprocessing services to other, usually smaller, countries in which such activities would not be economical.

10.5.2. Centralized facilities

A strategic choice can be made between centralized and site specific radioactive waste management facilities. Each approach has its merits. A centralized waste management facility capable of processing, storage and, possibly, the disposal of all, or a large part, of the radioactive waste in a country is usually more economic than the individual site approach, requires a smaller workforce than multiple individual sites and is likely to be more secure. On the

other hand, managing the waste at the site at which it is generated has the advantage of reducing the need for waste transport.

In fact, the choice is rarely made on purely economic grounds because there are usually local political factors, national historic nuclear development aspects, geographical factors and public opinion aspects to consider. Nevertheless, if strategy is being developed or upgraded, the choice between these options should be given proper consideration for all or parts of the waste management activities in the country.

10.5.3. Mobile processing facilities

A possible partial alternative to centralized radioactive waste management facilities, which has many of the same economic advantages, is the use of mobile processing facilities. Many waste processing systems are operated in 'batch' mode because a certain minimum amount of waste is usually needed for their efficient operation. Waste management costs for individual waste generators can be reduced if such processing systems are shared. Facilities with the potential for batch and mobile operation include supercompactors, disused sealed radioactive source conditioning appliances, liquid evaporation facilities, incineration facilities and metal melting facilities.

Mobile processing systems are available and are operating in some countries and beyond national borders. They are certainly an option to be considered when developing or updating the national strategy.

10.6. COUNTRY SPECIFICS

The selection of a waste management strategy in a country is often influenced by the nature and location of the country itself:

— *Proximity to other countries:* The proximity of the country to countries with well developed nuclear facilities will often influence the waste management strategy. In these circumstances, there is potential for sharing of technology and expertise. On the other hand, in countries which are geographically isolated from countries with nuclear expertise, independent solutions may be preferred.
— *Country size:* The size of the country may influence the choice of strategy. For example, in very large countries, the scope for centralization of national waste management facilities may be limited.

— *Population density:* In countries with high population densities, the siting of waste management facilities may be constrained and the number of potential sites limited.
— *Climate:* Climatic conditions may affect the selection of processing options. Technologies appropriate to local climatic conditions are to be preferred, e.g. solar evaporation. Temperature sensitive options should be avoided, e.g. bituminization in hot climates.
— Constraints on strategy selection.

10.6.1. Nuclear constraints

In selecting a waste management strategy, consideration should be given to the potential for deliberate misuse of nuclear material. This is a particular concern for fissile material held by some countries but also for spent high activity radiation sources used in medicine and industry which exist in many countries. Facilities in which such materials are held should be properly secured against theft and sabotage and, if necessary, measures should be taken to ensure that such materials are properly accounted for at all times [16, 39]. These are issues which can affect the choice of location and the nature of the waste management facility.

10.6.2. Other constraints

Other non-nuclear factors should be taken into account in developing facilities for the management of radioactive waste. These will vary from country to country but might include the limitations imposed by regulations on the chemical, biological or thermal content of effluents, on the protection of water resources and on environmental protection generally [40, 41].

10.7. PUBLIC SENSITIVITY

Public attitudes and expectations in relation to the potential construction of radioactive waste management facilities should be understood and addressed. Experience in many countries has shown that transparency and openness by the developer in relation to plans that may affect local communities offer the best chance of success. An important aim should be to gain the confidence and good opinion of the local community [42]. These are important aspects to take into account when developing and implementing strategies for radioactive waste management.

10.8. UNCERTAINTIES

Any plans may be disrupted or delayed by events affecting supply, construction and implementation. Effective planning should, therefore, take account of such possible uncertainties to the extent that they can be reasonably foreseen. Alternatives to the plans should be considered and adequate measures incorporated in the strategy implementation plan to reduce potential adverse impacts. Of course, not all eventualities can or need be taken into account and the focus should be on those which pose the most likely or most potentially disruptive threats. Such factors should be continuously monitored, assessed and evaluated in order to avoid serious delays and disruptions to the strategy implementation.

11. STRATEGY FORMULATION AND IMPLEMENTATION

The suggested steps to be followed in formulating and implementing a strategy for radioactive waste management are outlined in this section (Fig. 3).

As a basis for the formulation and implementation process, consideration should be given to the prerequisites for strategy development (Section 8), the options for managing different types of waste (Section 9) and considerations in selecting a strategy (Section 10).

11.1. STEP 1: REVIEW STATUS

Before this stage is reached, the strategy developer should be appointed.

The status with respect to the prerequisites specified in Section 8 should be assessed. If important information is missing, action should be taken to remedy the situation, e.g. gathering information on waste inventories, resources, etc.

It is noted here that the strategy may be developed for managing the waste in the whole country but also, it may be developed for one sector, for example, for the institutional waste in the country or the waste from nuclear power plants. The strategy may also be developed for a single company, e.g. the nuclear power plant operator (see also Section 2).

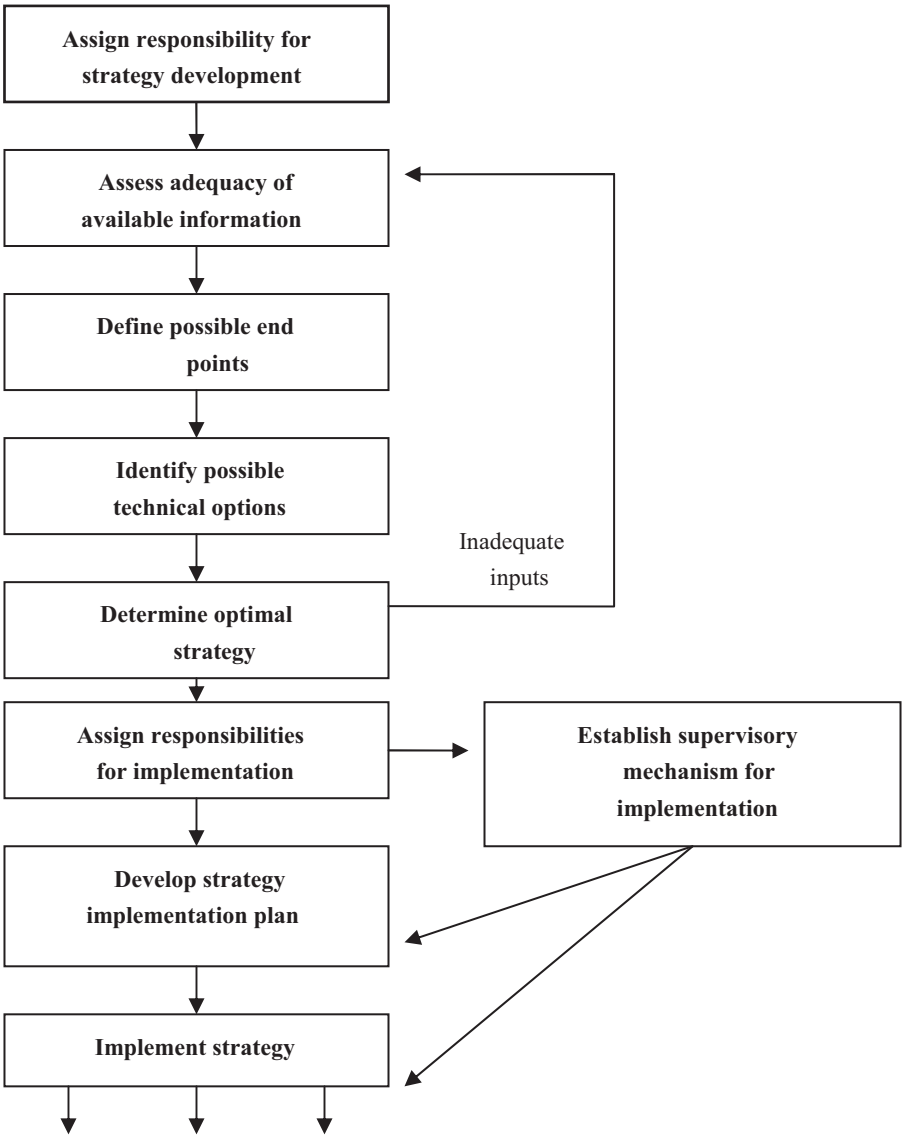

FIG. 3. Scheme of the strategy formulation and implementation process.

11.2. STEP 2: IDENTIFY END POINTS

For each waste category that is to be managed, the possible management end points should be identified (Section 9). Ideally, a disposal end point system should be selected (including existing and potentially suitable end points (see Annex II, Table 2)). If long term storage is considered within the strategy, the ultimate intended disposal end point should nevertheless be indicated. The strategies should address the long term fate of each waste category, for example, by identifying the period for which safe storage can be assured (minimum expected lifetime of waste packages) and plans for managing the waste beyond that time.

The result of this step should be a generic management pathway for each radioactive waste category.

11.3. STEP 3: IDENTIFY TECHNICAL OPTIONS

All the appropriate alternative technical management options for a radioactive waste category to reach the identified end points should be identified. The potential technical options can be narrowed down through the elimination of those that, for various reasons, are unsuitable. For example, the liquid discharge option may not be suitable in an arid country or incineration may not be acceptable for public sensitivity reasons. The considerations outlined in Section 10 and the indication of the relevance of strategy elements applicable within national waste management programmes of different magnitudes (see Annex II, Table 3) may be useful in this context.

The result will be a set of potential strategies for the safe management of a particular radioactive waste category.

11.4. STEP 4: DETERMINE OPTIMAL STRATEGY

The optimal strategy should be determined by comparison of the relative advantages and disadvantages of each strategy option (multi-attribute analysis). Typically, issues related to different processing technologies and their interdependence and synergies and relation to different disposal systems should be considered. It should be ensured that the chosen strategy can be implemented in the country, i.e. sufficient financial and technical resources exist and that there are no political, social or legal reasons to prevent its implementation. If multi-attribute analysis does not result in the selection of a

strategy which can be implemented, the end points should be redefined and the possible technical options re-analysed.

It should be noted that the multi-attribute approach described above may be suitable for countries with significant amounts and types of radioactive waste to manage, but for countries with one or only a few types of radioactive waste, the choice of optimum strategy will be straightforward and usually obvious, and can be reached without a formal analysis.

This optimization process should result in a general strategy which then needs to be further elaborated into an implementation plan.

11.5. STEP 5: ASSIGN RESPONSIBILITIES

Responsibilities for implementing particular parts of the strategy should be allocated, that is, for particular stages of the waste management process (for processing the waste, for waste disposal), but also for linkage between the stages.

The result will be an infrastructure for strategy implementation with defined responsibilities.

11.6. STEP 6: SUPERVISION OF IMPLEMENTATION

Control mechanisms should be established for ensuring the timely implementation of strategy (such as accountability criteria and periodic reviews). In order to ensure that the strategy is periodically reviewed and updated, appropriate mechanisms should be established (milestones for strategy reviews).

This results in the establishment of tools for the supervision of strategy implementation.

11.7. STEP 7: LONG TERM PLANNING

A long term strategic plan covering the expected lifetime of the programme and intermediate plans for the periods between significant milestones should be established. The plans should address the following matters:

— Assessment of data on radioactive waste generation: predicted waste inventories over time;

— Assessment of requirements for relevant technological equipment and facilities based on predictions of future radioactive waste generation;
— Specification of financial resources needed for technological and supporting equipment and facilities;
— Elaboration of an executive plan for the next budgeting period.

The result will be a strategy for the long term management of radioactive waste in the country (or for a specific waste stream) which includes the details of how it is to be implemented.

12. UPDATING POLICY AND STRATEGY

Policies and strategies may need to be updated from time to time. The following considerations may help in structuring such updating.

12.1. EXPERIENCE OBTAINED

The existing policy and strategy should be reviewed and analysed in relation to:

— The experience obtained in their application: to identify any deficiencies that could be improved upon. This could include making improvements in national structures for radioactive waste management, clarifying or modifying the roles and responsibilities of national organizations and making improvements in the funding arrangements for long term radioactive waste management.
— The experience obtained in other countries (e.g. those with similar spent fuel and radioactive waste management issues) as a way of identifying better policies and strategies. This could include identifying new technologies for radioactive waste management.

12.2. NEW NATIONAL CIRCUMSTANCES

Consideration should be given to any new national, political or technical circumstances that might require amendment of the policy and strategy, for example:

— New governmental arrangements and policies, e.g. revised changes in national policy on the import or export of radioactive waste;
— The closure or opening of nuclear facilities that might create new waste streams to be managed;
— Delays in developing waste storage/disposal facilities;
— The opening or closure of a national waste repository, which could influence the need for storage arrangements;
— The availability of regional or bilateral radioactive waste management facilities that might alter the national scheme for radioactive waste management, e.g. regional processing, storage or disposal.

12.3. NEW INTERNATIONAL AGREEMENTS

New international agreements that the country has become party to may have implications for spent fuel and radioactive waste management. This could also include arrangements with other countries on the export/import of disused sealed sources, spent nuclear fuel and radioactive waste for storage and/or disposal.

12.4. POLICY AND STRATEGY UPDATING

Based on this review, and if appropriate, changes to national policy and strategy for spent fuel management and radioactive waste management should be made. The lead in making changes to national policy should be taken by the government, but all relevant parties affected in the country should be involved and consulted. When the changes in the policy are approved by the government, consideration should be given to the need to modify national legislation and the national infrastructure for spent fuel and radioactive waste management. The lead in making changes to strategic plans should be taken by the waste owners, but again, all concerned parties should be consulted.

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Annex I

TYPICAL POLICY AND STRATEGY FOR A COUNTRY WITH A SMALL AMOUNT OF RADIOACTIVE WASTE

I–1. INTRODUCTION

The policy and strategy developed in this annex is an example of what might be established for a country with a small amount of radioactive waste to manage. It is based on the guidance provided in the main part of the report and elements have been selected from it to suit the requirements of a hypothetical country (Xland). In this country, radioactive waste arises from limited use of nuclear R&D facilities, e.g. a research reactor, and from the small scale use of radionuclides in industry and medicine. The country is assumed to have no nuclear power reactors or mining industries producing radioactive waste and no generation of NORM waste.

It is assumed that national legislation exists in Xland to provide for protection from the harmful effects of ionizing radiation. It is also assumed that basic information on the radioactive sources and radionuclides in use and approximate estimates of existing and future waste amounts are available.

The policy and strategy developed for Xland are simple and straightforward, and reflect the few types and small amounts of radioactive waste that have to be managed. For countries with a greater number of waste types and larger amounts of radioactive waste, additional policy and strategy elements would be needed.

The example policy and strategy are only intended as an aid to persons engaged in the development of national policy and strategies on radioactive waste management. In a real situation, they would have to be developed on the basis of the circumstances in that country.

I–2. EXAMPLE POLICY

I–2.1. Purpose

This policy sets out the aims and goals for the safe management of radioactive waste in Xland. It also establishes the roles and responsibilities of the organizations and bodies concerned with radioactive waste management in Xland.

I–2.2. General principles

The policy is consistent with the requirements of the national legislative system, relevant international principles and all international agreements to which Xland is signatory.

I–2.3. Policy statement

(a) The government of Xland (or identified ministry) will establish the legislative and regulatory framework regarding the safe management of radioactive waste. The framework will include a system for licensing radioactive waste management activities. It will appoint a regulatory body to enforce the legislation and regulations, and to issue licences (this may be the same organization that is responsible for enforcing legislation and regulations on radiation protection);
(b) The government of Xland (or identified ministry) will establish a national waste management organization responsible for the management of radioactive waste in the country (i.e. collection, processing, storage and disposal);
(c) The government of Xland will establish arrangements for providing the resources (financial, technical and human) to sustain the waste management organization and the regulatory body, and for the implementation of the radioactive waste management strategy;
(d) The licence holders of facilities generating radioactive waste will be responsible for the safe management of radioactive waste, until the waste is accepted by the waste management organization. The waste management organization will be responsible for the safe management of radioactive waste, including disused radioactive sources, for which no owner can be identified;
(e) The licence holders of facilities generating radioactive waste will adopt measures for minimizing the generation of radioactive waste;
(f) The waste management organization will prepare a strategy detailing arrangements for the long term management of radioactive waste in Xland for approval by the government;
(g) Radioactive waste will not be imported or exported unless approved by the government;
(h) The government of Xland will approve the import of sealed radioactive sources only on condition that they are accepted for disposal at the end of their useful lives by the supplier;
(i) The government of Xland (or the relevant ministry) will arrange the return of spent nuclear fuel from the research reactor to the country of its origin;

(j) All radioactive waste management activities will be conducted in an open and transparent manner, and the public will have access to information regarding waste management where this does not infringe upon national laws, security and defence.

I–3. EXAMPLE STRATEGY

I–3.1. Purpose

This strategy specifies the technical means and measures for managing the radioactive waste in Xland.

I–3.2. Strategy statement

(a) The waste management organization activities will be implemented according to the long term strategic plan and annual implementation plans, subject to governmental approval;
(b) The waste management organization will develop an inventory of the existing radioactive waste in the country, including legacy waste, and a prediction of expected future radioactive waste. The inventory will be kept up to date and appropriate records maintained;
(c) The waste management organization will establish a waste categorization scheme as a basis for the national radioactive waste inventory;
(d) The waste management organization, in cooperation with the regulatory body, will create and maintain a database of facilities at which radioactive waste is generated with details of the nature and amounts of waste involved;
(e) The waste management organization will establish and operate a system for the collection, characterization, transport, storage and processing of all radioactive waste generated in Xland. For this purpose, the waste management organization will specify the conditions under which the waste will be accepted from the waste generators;
(f) The waste management organization will provide for the eventual disposal of all radioactive waste in Xland according to the approved strategy;
(g) The waste management organization will report to the government on an annual basis concerning the activities performed in the period of the report, the amounts and types of radioactive waste that have been managed and on any other relevant issues.

TABLE II–3. OVERVIEW OF TECHNICAL OPTIONS FOR RADIOACTIVE WASTE MANAGEMENT

Waste type	Waste class	Source	Treatment	Concentrated stream form	Concentrated stream conditioning	Cleaned stream form	Cleaned stream conditioning	Disposal option for conditioned waste
Liquid	Exempt	Diverse sources	Discharge to the environment	No	N/A	No	N/A	N/A
	VSLW	Reactor, research, medical use	Storage for decay	Discharge to the environment	N/A	No	N/A	N/A
	VLLW	Decommissioning, research, site remediation, medical uses	Storage for decay, evaporation, membrane processes, ion exchange	Concentrate, spent resins, membranes	Cementation	Liquid	Discharge to the environment	Surface trench, landfill, near surface disposal
	LLW	Reactor operation and decommissioning, isotope production, U mining & milling, fuel fabrication, spent fuel reprocessing	Chemical treatment, ion exchange, membrane processes, evaporation	Sludge, spent resins, membranes, concentrate	Bituminization, cementation, polymerization, high integrity container	Liquid	Discharge to the environment	Near surface disposal
	ILW	Reactor operation and decommissioning, spent fuel reprocessing	Chemical treatment, ion exchange, membrane processes, evaporation	Sludge, spent resins, concentrate	Bituminization, cementation	LLW liquid, off-gas	See: LLW liquid, LLW gas	Intermediate depth disposal

TABLE II–3. OVERVIEW OF TECHNICAL OPTIONS FOR RADIOACTIVE WASTE MANAGEMENT (cont.)

Waste type	Waste class	Source	Treatment	Concentrated stream form	Concentrated stream conditioning	Cleaned stream form	Cleaned stream conditioning	Disposal option for conditioned waste
	HLW	Spent fuel reprocessing	Evaporation	Liquid, sludge	Vitrification	ILW liquid, off-gas	See: ILW liquid, ILW gas	Geological disposal
	Organic LILW	Research, reactor operation, spent fuel reprocessing	Incineration, sorption, distillation, wet oxidation, alkaline hydrolysis	Filters, sorbents, organic liquid	Cementation, polymerization	Liquid, off-gas	Recycle, discharge to the environment	Near surface disposal
Gaseous and airborne particles	LLW	Reactor operation, isotope production, waste processing	Filtration, sorption, scrubbing	Filters, sorption beds, liquids	Compaction, overpacking, cementation	Gas	Discharge to the environment	Near surface disposal
	ILW	Spent fuel reprocessing, waste processing	Filtration, sorption, scrubbing	Filters, sorption beds, liquids	Compaction, overpacking, cementation	Gas	Discharge to the environment	Near surface disposal
Solid	Exempt	Diverse sources	No	N/A	N/A	N/A	N/A	N/A
	VSLW	Research, medical use	Storage for decay	No	N/A	No	N/A	N/A
	VLLW	Site remediation research, reactor decommissioning, medical use	Storage for decay, fragmentation	Solids	N/A	Solid	Recycle/ discharge to the environment	Surface trench, landfill, near surface disposal

TABLE II–3. OVERVIEW OF TECHNICAL OPTIONS FOR RADIOACTIVE WASTE MANAGEMENT (cont.)

Waste type	Waste class	Source	Treatment	Concentrated stream form	Concentrated stream conditioning	Cleaned stream form	Cleaned stream conditioning	Disposal option for conditioned waste
	LLW	Reactor operation and decommissioning, isotope production and use, fuel fabrication, spent fuel reprocessing	Compaction, supercompaction, incineration, melting, fragmentation	Solid, ash, ingots	Grouting, overpacking	Off-gas	See: LLW gas	Near surface disposal, BOSS*
	ILW	Reactor operation and decommissioning, isotope use, spent fuel reprocessing	Compaction, supercompaction, fragmentation	Solid	Grouting, overpacking	No	N/A	Intermediate depth disposal, geological disposal, BOSS*
	HLW	Use of sealed radioactive sources	Encapsulation, overpacking	No	N/A	No	N/A	Intermediate depth disposal, geological disposal, BOSS*

* BOSS: borehole disposal of disused sealed sources.

TABLE II–3. OVERVIEW OF RECOMMENDED MANAGEMENT END POINTS FOR PARTICULAR WASTE STREAMS

Radioactive waste stream		End point							
		Long term storage*	Decay storage	Surface trench	Tailing dam	Engineered surface facility	Intermediate depth facility	Geological repository	BOSS
VSLW	Low volume	+	++	+	+	+	NR	NR	NR
	Large volume	+	++	+	+	NR	NR	NR	NT
VLLW	Low volume	NR	+	++	++	+	NR	NT	NR
	Large volume	NR	+	++	++	+	NR	NT	NT
LLW	Low volume	+	NR	++	++	++	++	+	+
	Large volume	+	NR	+	+	++	++	+	NT
ILW	Low volume	+	N	N	N	+	++	++	+
	Large volume	+	N	N	N	N	++	++	NT

TABLE II–3. OVERVIEW OF RECOMMENDED MANAGEMENT END POINTS FOR PARTICULAR WASTE STREAMS (cont.)

Radioactive waste stream		End point							
		Long term storage*	Decay storage	Surface trench	Tailing dam	Engineered surface facility	Intermediate depth facility	Geological repository	BOSS
SNF/HLW		+	N	N	N	N	N	++	N
DSRS	Short lived	+	+	+	NR	++	+	+	+
	Long lived	+	N	N	N	+	++	++	++
	HARS	+	N	N	N	N	++	++	++
NORM	Low volume	NR	N	++	++	+	+	NR	NR
	Large volume	NR	N	++	++	NR	NR	NR	NT

TABLE II–3. OVERVIEW OF RECOMMENDED MANAGEMENT END POINTS FOR PARTICULAR WASTE STREAMS (cont.)

Radioactive waste stream		End point							
		Long term storage*	Decay storage	Surface trench	Tailing dam	Engineered surface facility	Intermediate depth facility	Geological repository	BOSS
Uranium milling & mining	Low volume	NR	N	+	++	+	+	+	NR
	Large volume	NR	N	+	++	NR	NR	NR	NT

*: Long term storage is an end point only for radioactive waste stored for decay; otherwise it must be followed by a disposal option.
++: Preferable solution.
+: Acceptable solution.
N: Not possible for safety reasons.
NT: Not possible for technical reasons.
NR: Possible but needs to be assessed from technical or economic points of view.
BOSS: Borehole disposal facility.
SHARS: Spent sealed high activity radioactive sources.

TABLE II–3. ELEMENTS TO BE CONSIDERED DURING DEVELOPMENT OR REVISION OF A RADIOACTIVE WASTE MANAGEMENT STRATEGY

	Case Country A[1]	Case Country B[2]	Case Country C[3]	Case Country D[4]	Case Country E[5]
Prerequisites for strategy formulation stage					
National inventory: • Waste classification; • Waste amounts and types; • Waste characterization	Fully required	Fully required	Fully required	Fully required	Fully required
Existing national radioactive waste management policies or policies under development	Fully required	Fully required	Fully required	Fully required	Fully required
Waste management strategies of waste owners in the country (or abroad)	Fully required	Fully required	To the extent of programme needs	To the extent of programme needs	To the extent of programme needs
Availability of accessible existing and/or anticipated radioactive waste management facilities	Fully required	Fully required	Fully required	To the extent of programme needs	To the extent of programme needs
Availability of resources, funds to support radioactive waste management	Fully required	Fully required	Fully required	Fully required	Fully required
Existing regulatory regime	Fully required	Fully required	Fully required	Fully required	Fully required
Stakeholder expectations and interests	Fully required	Fully required	Fully required	Fully required	Fully required

TABLE II–3. ELEMENTS TO BE CONSIDERED DURING DEVELOPMENT OR REVISION OF A RADIOACTIVE WASTE MANAGEMENT STRATEGY (cont.)

	Case Country A[1]	Case Country B[2]	Case Country C[3]	Case Country D[4]	Case Country E[5]
Technical options to be considered in strategy formulation stage					
Authorized discharge of gaseous and liquid waste					
Discharge	To be considered	To be considered	To be considered	To be considered	Should be considered
Very short lived waste					
Decay storage until clearance	To be considered	To be considered	To be considered	To be considered	Not applicable
Very low level solid waste					
Processing: • Sorting of contaminated soil; concrete, waste; • Fragmentation of large items; • Compaction; • Incineration	All options require consideration	All options require consideration	Some options may be considered	Some options may be considered	Not usually required
Storage	Fully required	Fully required	Fully required	Might be required	Fully required
Disposal — VLLW landfill	Fully required	Fully required	Fully required	Might be required	Fully required

TABLE II–3. ELEMENTS TO BE CONSIDERED DURING DEVELOPMENT OR REVISION OF A RADIOACTIVE WASTE MANAGEMENT STRATEGY (cont.)

	Case Country A[1]	Case Country B[2]	Case Country C[3]	Case Country D[4]	Case Country E[5]
LILW					
Liquid waste processing options (resulting waste): • Chemical methods (sludge); • Evaporation (concentrate); • Ion exchange (resins); • Membrane methods (filters/membranes); • Incineration (ash, slag, filters, sludge)	All options require consideration	All options require consideration	Some options may be considered	Some options may be considered	Not applicable
Gaseous waste processing options (resulting waste): • Off-gas systems (sorbent beds, filters, sludge); • Gas separation (flasks)	All options require consideration	All options require consideration	Some options may be considered	Not applicable	Not applicable
Solid waste processing options: • Fragmentation; • Incineration; • Compaction; • Melting	All options require consideration	All options require consideration	Some options may be considered	Some options may be considered	Not applicable

TABLE II–3. ELEMENTS TO BE CONSIDERED DURING DEVELOPMENT OR REVISION OF A RADIOACTIVE WASTE MANAGEMENT STRATEGY (cont.)

	Case Country A[1]	Case Country B[2]	Case Country C[3]	Case Country D[4]	Case Country E[5]
Liquid waste conditioning options: • Cementation; • Bituminization; • Polymerization; • Vitrification	All options require consideration	All options require consideration	Some options may be considered	Some options may be considered	Not applicable
Solid and solidified waste conditioning options: • Packaging; • Containerization; • Overpacking; • High integrity containers	All options require consideration	All options require consideration	All options require consideration	Some options may be considered	Not applicable
Storage: • Storage for decay; • Storage awaiting disposal; • Prolonged (long time) storage	All options require consideration	All options require consideration	All options require consideration	Some options may be considered	Some options may be considered
Disposal of LLW: • Near surface repository; • Geological repository	All options require consideration	All options may require consideration	Some options may be considered	Some options may be considered	Some options may be considered
Disposal of ILW: • Geological repository	Requires consideration	Requires consideration	May be considered	Not applicable	Not applicable

TABLE II–3. ELEMENTS TO BE CONSIDERED DURING DEVELOPMENT OR REVISION OF A RADIOACTIVE WASTE MANAGEMENT STRATEGY (cont.)

	Case Country A[1]	Case Country B[2]	Case Country C[3]	Case Country D[4]	Case Country E[5]
HLW and spent fuel					
Spent fuel storage: • Wet storage in pools; • Dry storage in containers/vaults	All options require consideration	All options require consideration	All options may require consideration	Not applicable	Not applicable
Spent fuel conditioning for disposal: • Encapsulation; • Overpacking for disposal	All options require consideration	All options require consideration	May be considered	Not applicable	Not applicable
High level solid waste processing: • Fragmentation	Requires consideration	Requires consideration	May be considered	Not applicable	Not applicable
High level liquid waste conditioning: • Vitrification; • Packaging for storage/disposal; • Overpacking	All options require consideration	Not applicable	Not applicable	Not applicable	Not applicable
HLW storage: • Storage awaiting disposal; • Long term storage	All options require consideration	All options require consideration (for spent fuel)	Some options may be considered	Not applicable	Not applicable

TABLE II–3. ELEMENTS TO BE CONSIDERED DURING DEVELOPMENT OR REVISION OF A RADIOACTIVE WASTE MANAGEMENT STRATEGY (cont.)

	Case Country A[1]	Case Country B[2]	Case Country C[3]	Case Country D[4]	Case Country E[5]
Disposal of spent fuel/HLW: • Geological repository with/without retrievability	Requires consideration	Requires consideration (for spent fuel)	Some options may be considered	Not applicable	Not applicable
Disused sealed radiation sources					
Repatriation to the original manufacturer	Requires consideration	Requires consideration	Requires consideration	Requires consideration	Not applicable
Processing: • Encapsulation; • Immobilization in metal matrix	All options require consideration	All options require consideration	All options require consideration	All options require consideration	Not applicable
Conditioning for storage and disposal: • Packaging	Requires consideration	Requires consideration	Requires consideration	Requires consideration	Not applicable
Storage options determined by the source type: • Storage to decay; • Storage as LILW; • Storage as HLW	All options require consideration	All options require consideration	All options require consideration	All options require consideration	Not applicable

TABLE II–3. ELEMENTS TO BE CONSIDERED DURING DEVELOPMENT OR REVISION OF A RADIOACTIVE WASTE MANAGEMENT STRATEGY (cont.)

	Case Country A[1]	Case Country B[2]	Case Country C[3]	Case Country D[4]	Case Country E[5]
Disposal options determined by the source type: • Co-locate with LLW; • Co-locate with ILW/HLW; • Borehole	All options require consideration	All options require consideration	Some options may be considered	Some options may be considered (e.g. borehole)	Not applicable
Synergies of technical options for management of different waste streams for: • Processing; • Storage; • Disposal	Fully required	Fully required	Fully required	Some synergies could be identified	Some synergies could be identified

[1] Radioactive waste from nuclear power plants, front and back end fuel cycle facilities, wide use of nuclear R&D facilities, and extensive nuclear applications in industry and medicine.

[2] Radioactive waste from nuclear power plants, wide use of nuclear R&D facilities, extensive nuclear applications in industry and medicine. No fuel cycle facilities.

[3] Radioactive waste from limited use of nuclear R&D facilities, research reactor, limited use of nuclear applications in industry and medicine. No nuclear power plant, no fuel cycle facilities.

[4] Radioactive waste from limited use of nuclear applications in industry and medicine. No reactors, no fuel cycle facilities, no nuclear R&D.

[5] Only NORM waste is generated.

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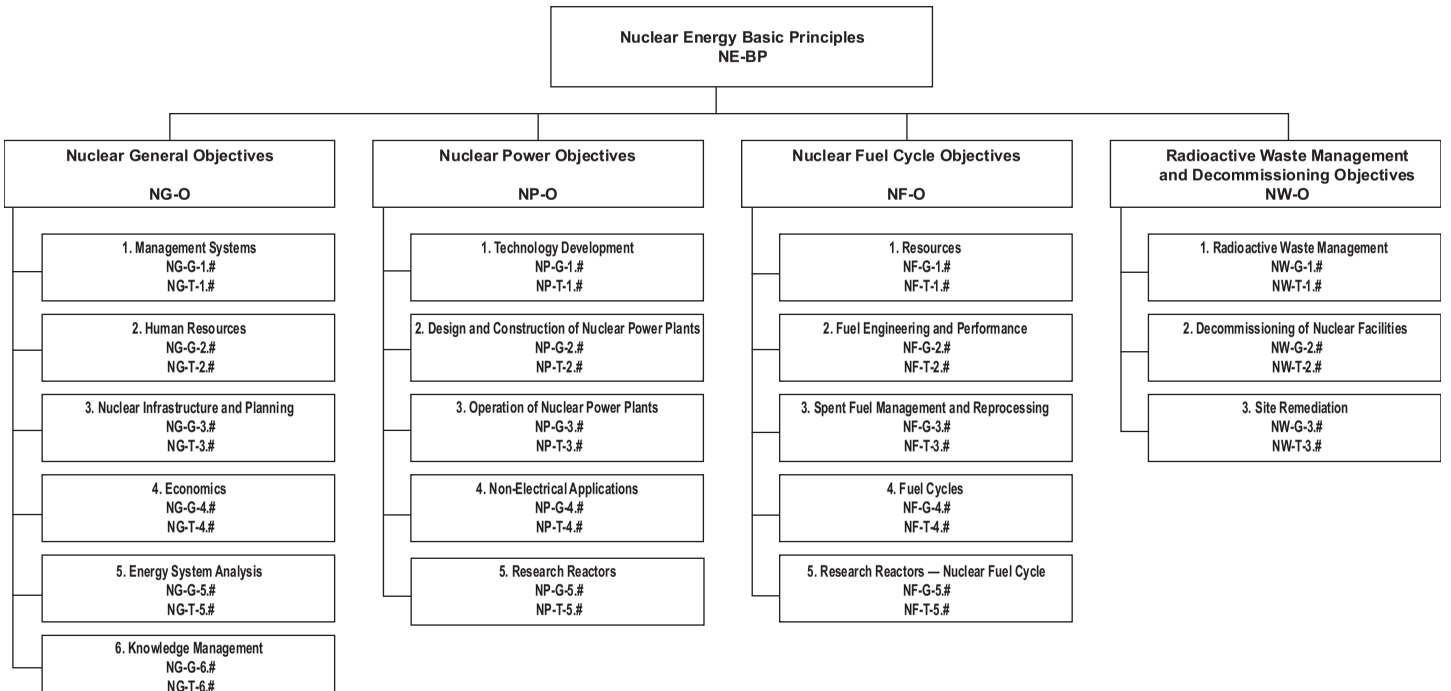

Key

BP: Basic Principles
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G: Guides
T: Technical Reports
Nos. 1-6: Topic designations
#: Guide or Report number (1, 2, 3, 4, etc.)

Examples

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