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# Policies and Strategies for the Management of NORM Residues and Wastes

GUIDES

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# POLICIES AND STRATEGIES FOR THE MANAGEMENT OF NORM RESIDUES AND WASTES

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IAEA NUCLEAR ENERGY SERIES No. NW-G-3.4

# POLICIES AND STRATEGIES FOR THE MANAGEMENT OF NORM RESIDUES AND WASTES

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Publishing Section
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
tel.: +43 1 2600 22529 or 22530
email: sales.publications@iaea.org
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# FOREWORD

The IAEA's statutory role is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world". Among other functions, the IAEA is authorized to "foster the exchange of scientific and technical information on peaceful uses of atomic energy". One way this is achieved is through a range of technical publications including the IAEA Nuclear Energy Series.

The IAEA Nuclear Energy Series comprises publications designed to further the use of nuclear technologies in support of sustainable development, to advance nuclear science and technology, catalyse innovation and build capacity to support the existing and expanded use of nuclear power and nuclear science applications. The publications include information covering all policy, technological and management aspects of the definition and implementation of activities involving the peaceful use of nuclear technology. While the guidance provided in IAEA Nuclear Energy Series publications does not constitute Member States' consensus, it has undergone internal peer review and been made available to Member States for comment prior to publication.

The IAEA safety standards establish fundamental principles, requirements and recommendations to ensure nuclear safety and serve as a global reference for protecting people and the environment from harmful effects of ionizing radiation.

When IAEA Nuclear Energy Series publications address safety, it is ensured that the IAEA safety standards are referred to as the current boundary conditions for the application of nuclear technology.

Many industrial operations use or process materials containing natural radionuclides, the activity concentration of which can be significantly enhanced in the residues (including waste) and effluents generated by processing. These materials are referred to as naturally occurring radioactive material (NORM). The large amount of NORM residues generated in many countries demands complex national policies and strategies to comply with legal frameworks and meet environmental and sustainability targets.

In brief, a country's national policy serves as a commitment to address the safe management of NORM residues in a sustainable, coordinated and cooperative manner. The policy is typically established by the government, and it varies from country to country to account for specific national circumstances (e.g. economic, geographic or transboundary settings) and perspectives, as well as the amount, physical nature and chemical composition of the NORM residues produced. In turn, the national strategy sets out the means (organizational, technical, etc.) to achieve the goals and requirements set out in the national policy.

This publication describes the basic principles and objectives that the national policy on NORM residues management can be built on and the elements to be considered when developing such a policy. These basic principles include safety, sustainability and circularity in NORM residues management and are in line with the IAEA Fundamental Safety Principles and safety standards, as well as the United Nations Sustainable Development Goals. Guidance is also provided on key policy elements, such as assignment of responsibilities; establishment of a national NORM waste inventory as a basic tool informing policy and strategy; assurance of infrastructure and financing needs; mechanisms for public participation; and coordination with other related policies and strategies.

A structured framework for establishing a national strategy for NORM residues management is also proposed, consisting of several steps within each of the three phases of the strategy development cycle (development; implementation; review and update). The actions and means needed to complete each step are also discussed, with a focus on ensuring safety while fostering sustainability.

This publication is aimed at supporting all personnel concerned with the development, implementation and review of such policies and strategies (policy makers, regulators, facility operators, waste managers and other interested parties). The guidance provided is applicable to the life cycle management of solid NORM residue, regardless of the country's prevailing situation and of whether NORM waste is declared as radioactive waste by the country. The publication represents the opinions of international NORM experts but does not constitute recommendations made based on a consensus of the Member States.

The IAEA wishes to acknowledge all those who contributed to the drafting and review of this text. The IAEA officer responsible for this publication was H. Monken-Fernandes of the Division of Nuclear Fuel Cycle and Waste Technology.

# CONTENTS

# 1. INTRODUCTION

The adoption of a national policy and strategy (P&S) for naturally occurring radioactive material (NORM) management allows the relevant residue owners or facility operators in specific industry sectors to develop their own strategies aligned with the national objectives. A P&S also encourages private waste management companies to enter the market and facilitate the provision of the necessary services, including measurement (radionuclide activity concentration) and professional training and expertise. This will result in improved and more effective country outcomes insofar as the P&S is successful in bringing together a wide group of stakeholders.

## 1.1. BACKGROUND

Industrial production is driven by two ways: the circular economy or the linear economy. The linear economy model has been in use since industrialization began, whereas the circular economy model is a more recent approach that was first proposed in the 1960s. The traditional linear economy follows the pattern of ‘take–make–dispose’, whereas the focus of the circular economy is to maintain the added value of materials while eliminating the generation of waste as much as possible.

Within the concept of the linear economy, any substance that the holder ends up discarding or is required to discard can be considered waste. However, some materials that are generated during a production process but are not the target product of the process itself can still have economic value. That is, waste materials can lose their waste characteristics and be seen as residues; although, the line that separates waste materials from residues is, of course, tenuous. Within the concept of the circular economy, every material coming out of an industrial process could ideally serve a beneficial use. The terms ‘by-products’ and ‘co-products’ are often used when talking about production processes. By-products can be considered as secondary products obtained incidentally during the manufacturing process of the main product. Co-products are valuable materials that are generated during a production run together with the main product. They differ from by-products because their production is deliberate.

The IAEA Nuclear Safety and Security Glossary (referred to as Glossary) provides a simple definition for waste: “Material for which no further use is foreseen” [1]. This definition also applies to NORM waste, which is defined in the Glossary: “*Naturally occurring radioactive material* for which no further use is foreseen" [1]. The Glossary provides a more specific definition of radioactive waste:

> "…material for which no further use is foreseen that contains, or is contaminated with, radionuclides at *activity concentrations* greater than *clearance levels* as established by the *regulatory body*" [1].

The publication stresses that:

> "It should be recognized that this definition is purely for regulatory purposes, and that material with *activity concentrations* equal to or less than *clearance levels* is *radioactive* from a physical viewpoint, although the associated radiological *hazards* are considered negligible" [1].

On the other hand, the Glossary does not provide a definition for residue alone but does define NORM residue as "Material that remains from a *process* and comprises or is contaminated by *naturally occurring radioactive material (NORM)*". The Glossary highlights that "A *NORM residue* may or may not be *waste*" [1].

With these definitions in mind, this publication will work with the understanding that if a material generated in a production can serve a beneficial use and that use is authorized by the relevant regulatory authorities, it is to be seen as a residue. On the other hand, if such material has no other destination but disposal, whether because no beneficial use can be assigned or because the use cannot be warranted because of safety considerations, then this material is to be treated as waste.

Many industrial operations use or process (raw) materials containing natural radionuclides. The activity concentrations of these radionuclides can be enhanced in the process residues compared with their values in the raw material. If disposal is the destination of such residues because they have no beneficial use or because the use, as mentioned above, is not warranted, then they will be seen as NORM waste. This decision combines technical, economic and safety (regulatory) considerations.

Operations potentially involving NORM residues are well known and include [2]:

— Extraction of rare earth elements;
— Production and use of thorium and its compounds;
— Production of niobium and ferroniobium;
— Mining of ores, including uranium ore;
— The zircon and zirconia industries;

— Manufacture of titanium dioxide pigment;
— The phosphate industry;
— Production of iron and steel, tin, copper, aluminium, zinc and lead;
— Combustion of coal;
— Production of oil and gas;
— Water treatment;
— Geothermal energy production.

It is important to note that different industrial processes yield diverse types and amounts of NORM residues by virtue of the characteristics of the raw material and the process itself.

A specific feature of most of the above listed industries is that the amount of residues they generate can be very large. Broadly speaking, two main categories of NORM residues can be distinguished: (a) residues with low to moderate radionuclide activity concentrations above background levels, produced in very large amounts of the order of several thousand tonnes per year (such as muds and sludge); and (b) residues with higher activity concentrations, usually generated in small amounts (such as pipe scales or process filters).

In recent years, international efforts to create sustainable economic growth by promoting circular economy models have led NORM related industries to seek innovative methods of residue valorization, avoiding the management of these materials as waste. These efforts, in line with the so-called waste management hierarchy, contribute to the objectives of the circular economy as well as reducing waste management costs. Nonetheless, it has to be underscored that for NORM residues, the presence of radioactive isotopes (in addition to other potentially hazardous substances) needs to be accounted for to ensure safety in their reuse, recycling or recovery. Successful examples of NORM residue valorization include the use of phosphogypsum as a soil amendment in agriculture and as an additive in building materials. The use of coal ash as a cement additive and the reprocessing of uranium legacy tailings for Nb extraction are also worthy of mention. However, despite such initiatives, large amounts of NORM residues still need to be disposed of as waste.

When NORM related facilities are improperly managed, NORM residues can lead to undue exposure of workers and members of the public to ionizing radiation. The same is true for legacy sites at which past NORM related activities resulted in environmental contamination. Undue exposures and environmental impacts can also be associated with the decommissioning of industrial NORM related facilities if radiation controls are not implemented.

Consequently, to prevent those adverse effects, a governmental, legal and regulatory framework for the control of NORM residues is necessary in most countries [3]. This notion is put forward in the first requirement of IAEA Safety

Standards Series No. GSR Part 1 (Rev. 1), Governmental, Legal and Regulatory Framework for Safety [4], where it is stated that:

> "The government shall establish a national policy and strategy for safety, the implementation of which shall be subject to a graded approach in accordance with national circumstances and with the radiation risks associated with facilities and activities, to achieve the fundamental safety objective and to apply the fundamental safety principles established in the Safety Fundamentals."

According to IAEA Safety Standards Series No. SSG-60, Management of Residues Containing Naturally Occurring Radioactive Material from Uranium Production and Other Activities [5], to ensure that NORM residues are managed in a safe way and in a sound and cost effective manner: "The government should establish a policy and strategy that is appropriate to the national situation".

In the case of NORM residues, the P&S would acknowledge existing governmental, legal and regulatory frameworks; contribute to the promotion of a graded approach to regulation; assist in identifying further industries that might need oversight; and coordinate the overall approach to the management of NORM residues.

In brief, the national policy will serve as a country's commitment to address the safe management of NORM residues in a sustainable, coordinated and cooperative manner. The policy will typically be established by the government, and it will vary by country. This reflects the fact that policies are not only based on scientific evidence and general principles but also need to account for specific national circumstances (e.g. economic, geographic or transboundary settings) and perspectives, as well as the amount, physical nature and chemical composition of the NORM residues produced.

In turn, the national strategy will describe the means (organizational, technical, etc.) to achieve the goals and requirements set out in the national policy.

In this publication, policy and strategy are considered separately; however, some countries may not make such a distinction but could instead establish a national plan combining both into a single document. Moreover, countries in which NORM waste is classified as radioactive waste could integrate their policy for NORM residues into their national policy on radioactive waste management. This could be elaborated and implemented in several strategies that address different types of waste, including NORM (e.g. nuclear reactor waste, decommissioning waste, medical waste, NORM waste, etc.), or waste belonging to different owners [6].

This publication has been developed under the IAEA Environet (Network of Environmental Remediation and NORM Management) NORM project, which is aimed at sharing international experience and good practice in environmental remediation and NORM management, as well as providing targeted assistance and responding to the needs of Member States. The valuable experience accumulated by different Member States has been captured in this publication. Other aspects outlined here will be developed in further detail by the various working groups of the Environet NORM project. It is worth mentioning that detailed guidance and suggestions on possible approaches and strategies to be considered in the valorization of NORM residues, particularly within the scope of the concept of the circular economy, will be provided in another dedicated publication being produced under the Environet NORM project. As a result, this publication focuses on P&S with regard to NORM residues when these materials are classified as waste.

## 1.2. OBJECTIVE

The objective of this publication is to provide guidance on the establishment of a national P&S for the management of NORM residues, including those generated in the decommissioning of NORM related facilities and in the remediation of legacy sites. In line with current international trends and efforts, the United Nations (UN) Sustainable Development Goals (SDGs)[1] [7] are acknowledged in this publication as relevant guiding principles for the life cycle management of NORM residues, while a focus is kept on radiation safety implications.

This guidance is aimed at supporting Member States in establishing their national P&S in alignment with the IAEA Safety Standards, particularly SSG-60 [5]. It seeks to assist all those concerned with the development, implementation and review of such a P&S by providing a comprehensive and structured framework. It also identifies and illustrates the various elements and tools at the disposal of policy makers to be used and applied in consultation with all role players and stakeholders.

Guidance and recommendations provided here in relation to identified good practices represent expert opinion but are not made on the basis of a consensus of all Member States.

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[1] In 2015, world leaders agreed to 17 global goals (officially known as the Sustainable Development Goals, or SDGs). These goals aim to create a better world by 2030, by ending poverty, fighting inequality and addressing the urgency of climate change.

## 1.3. SCOPE

This publication is devoted to the development, implementation and review of the national P&S for NORM residues management, regardless of their origin, chemical composition or ownership status. It covers solid residues generated by the whole range of NORM involving the industrial sectors listed in Ref. [2], excluding uranium mining and processing. Operational radioactive liquid and gaseous effluent discharges released to the environment under the authority of the relevant regulators are not covered in this publication.

NORM residues management refers to all activities that relate to the handling, pretreatment, treatment (including valorization), conditioning, storage or disposal of NORM residues and off-site transportation. However, because the first steps of sustainable waste management are waste prevention and minimization, the involvement of waste generators is essential to the success of a P&S. Thus, in the scope of this publication, a life cycle approach to NORM residues management is adopted.

As a result of the multifaceted nature of NORM residues, several other interconnected areas are relevant to their management, such as remediation of radiologically contaminated land; decommissioning of NORM related facilities; environmental pollution control; and management of non-hazardous and hazardous industrial waste. Policies related to the above mentioned areas are not covered in this publication. However, whenever necessary, their overlap with policy for NORM residues management is highlighted, indicating the need for proper coordination among such areas.

This guidance provides a structured framework for establishing national policies and strategies on NORM residues management in consultation with all relevant interested parties. Nevertheless, it does not prescribe their content, as this will be largely dependent on national priorities and circumstances.

## 1.4. STRUCTURE

Section 2 presents the policy fundamentals and underlying objectives, concepts and principles in the context of NORM residues management and sets out the basic concepts and definitions used in this publication. It also describes the need for the national policy to secure the sustainability of waste management by a transition to circular economy models.

In Section 3, the elements to be considered in developing the national policy are described, including, among others, the assignment of responsibilities, funding infrastructure requirements and public communication and participation.

The different policy instruments to be used when establishing the national P&S are also discussed.

Section 4 proposes a structured framework to develop a national strategy aimed at delivering policy objectives, consisting of a development phase, an implementation phase, and a review and update phase. The steps proposed within this framework are applicable universally, regardless of the country's prevailing circumstances and the characteristics of the national NORM residues inventory.

Section 5 presents the main conclusions arising from this publication.

# 2. POLICY FUNDAMENTALS AND UNDERLYING OBJECTIVES, CONCEPTS AND PRINCIPLES

The UN SDGs for 2030 are supported by 169 targets [7], some of which are specific to waste management. Namely, these are to "…achieve the environmentally sound management of chemicals and all wastes throughout their life cycle…" (Goal 12, Target 12.4) and to "…substantially reduce waste generation through prevention, reduction, recycling and reuse" (Goal 12, Target 12.5).

All countries share these common goals on waste and NORM residues management as part of their waste inventories. Any national policy on NORM residues management would need to make a clear statement regarding the SDGs. The policy would need to be developed by means of robust assessment and deliberation over the possible ways to achieve its objectives, taking account of the national governance and the socioeconomic circumstances.

## 2.1. INTRODUCTION

The IAEA has already issued a publication that covers the subject of policies and strategies for radioactive waste management in IAEA Nuclear Energy Series, No. NW-G-1.1, Policies and Strategies for Radioactive Waste Management [6]. That publication makes reference to NORM, recognizing that it is important that national policy should indicate the regulatory regime under which NORM is managed. The critical importance of such a decision will be discussed in Section 2.4. The present publication is applicable both for countries where NORM waste is declared as radioactive waste and countries where it is not. However, in the former case, the guidance in this document needs to be interpreted and applied without prejudice to the application of the guidance provided in Ref. [6].

This section of the publication explores the basic principles and elements that a national policy on NORM residues management needs while keeping a life cycle approach in mind.

## 2.2. SAFETY OBJECTIVES

Policy objectives identify what is needed to achieve policy goals. Ensuring the application of the inherent safety principles needs to be a cornerstone of the national policy for the life cycle management of NORM residues.

The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation and applies to all circumstances that give rise to radiation risks. The IAEA has established principles ensuring compliance with this safety objective in IAEA Safety Standards Series No. SF-1, Fundamental Safety Principles [8]. Many of these principles are relevant to the management of NORM residues. In particular, the policy on NORM residues — in combination with the applicable legal and regulatory framework — needs to ensure that these are managed in such a way as to:

- Secure an acceptable level of protection for human health.
- Provide an acceptable level of protection of the environment.
- Ensure that possible effects on human health and the environment beyond national borders will be considered.
- Ensure predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today.
- Ensure the implementation of the 'as low as reasonably achievable' (ALARA) principle regarding occupational and public exposures arising from the management of NORM residues and the application of a graded approach in the control of the facilities.
- Avoid imposing undue burdens on future generations.
- Rely on an appropriate national legal framework and provision for independent regulatory functions.
- Consider interdependencies among all steps in NORM residues generation and management.
- Have in place an appropriately assured framework that provides for the inherent safety of facilities for NORM waste management.

## 2.3. KEY CONCEPTS

Natural sources of radiation comprise the Sun and other stars (sources of cosmic radiation) and rocks and soils (terrestrial sources of radiation). They can also comprise any material whose radioactivity is for all intents and purposes due only to radionuclides of natural origin, such as products or residues from the processing of minerals. Radioactive materials of natural origin to be used in nuclear installations for their radioactive characteristics and radioactive waste generated in such installations are excluded from this category.

The Glossary [1] defines NORM as radioactive material containing no significant amount of radionuclides other than radionuclides of natural origin. The term 'radionuclides of natural origin' means radionuclides that occur naturally in significant quantities on Earth. The term is usually used to refer to the primordial radionuclides such as $^{40}K$, $^{235}U$, $^{238}U$, $^{232}Th$ and their radioactive decay products. It is important to observe that the Glossary does not provide a clear definition of 'significant amounts' and indicates that such determination is to be made by the relevant regulatory authority. The term NORM also includes those materials in which the activity concentrations of naturally occurring radionuclides have been enhanced by manufacturing processes.

NORM residue is defined in Ref. [1] as material generated through process streams that remains and comprises or is contaminated by NORM. NORM residues for which no further use is foreseen are defined as NORM waste (see Fig. 1).

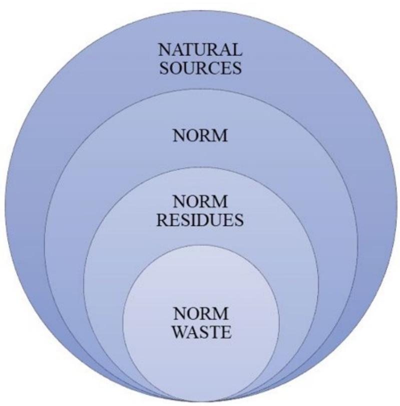


*FIG. 1. Primary diagram showing the relationship between NORM residues and other related concepts discussed in Section 2.3.*

Waste materials can be reused, recycled or composted to be converted into useful products including materials, chemicals, fuels or other sources of energy. All these processes are generically referred to as waste valorization.

Whereas most countries share the same definitions for residues and waste, other terms related to the circular economy are frequently misunderstood because of the lack of a common international language and the lack of consistency in the associated regulatory implications.

For example, in the context of the European Union's waste legislation, residues can be defined either as waste or as by-products. The European Waste Framework Directive defines a by-product as a substance or object resulting from a production process, the primary aim of which is not the production of that specific item [8]. Still according to Ref. [9], for a residue to be considered as a non-waste by-product, four conditions have to be met:

"(a) further use of the substance or object is certain;
(b) the substance or object can be used directly without any further processing other than normal industrial practice;
(c) the substance or object is produced as an integral part of the production process; and further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts."

In the United States of America, a by-product is defined similarly (i.e. as a material that is not a primary product of a production process and is not solely or separately produced by the production process). But unlike the European approach, 'by-product' is also a catch-all term that includes most wastes that are not spent materials or sludge and refers to "materials, generally of a residual character, that are not produced intentionally or separately, and that are unfit for end use without substantial processing" [9]. By-products are regulated as solid waste when used in a manner constituting disposal; burned for energy recovery, used to produce a fuel or contained in fuels; or accumulated speculatively [10].

Also relevant to the policy for NORM is the definition provided by the IAEA Safety and Security Glossary of radioactive waste [1], as already described in Section 1. The Glossary indicates that this definition is to be used in the context of legal and regulatory purposes. As will be discussed in more detail in Section 2.4, the fact that a given waste is classified as NORM does not imply it will be legally defined as radioactive waste.

### 2.3.1. The concepts of exemption, exclusion and clearance

These are three important concepts to be considered when formulating a P&S for NORM. The concept of clearance is a basic tool in the application of the graded approach to regulation, together with the concepts of exclusion and exemption.

Exclusion is defined as:

> "The deliberate excluding of a particular type of *exposure* from the scope of an instrument of *regulatory control* on the grounds that it is not considered amenable to *control* through the regulatory instrument in question" [1].[2]

Exemption applies to those situations, as determined by a regulatory body, in which:

> "…a *source* or *practice* need not be subject to some or all aspects of *regulatory control* on the basis that the *exposure* and the *potential exposure* due to the *source* or *practice* are too small to warrant the application of those aspects or that this is the optimum option for *protection* irrespective of the actual level of the *doses* or *risks*" [1].

Finally, clearance is "Removal of *regulatory control* by the *regulatory body* from *radioactive materia*l or *radioactive* objects within notified or authorized *facilities and activities*" [1].

Materials are cleared on the basis that radiation risks arising from the cleared material are sufficiently low as not to warrant regulatory control, or continued regulatory control of the material would yield no net benefit. The basic assumptions behind each of the three above defined concepts are summarized in Table 1.

The application of these concepts is discussed in detail in Ref. [13], which has since been revised as two separate publications covering, respectively, exemption [11] and clearance [12]. Both refer extensively to the application for NORM. In brief, the same approach as in IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [14] is followed: a case by case exemption is applied for bulk materials containing radionuclides of natural origin, using an individual dose criterion of the order of 1 mSv in a year, whereas 1 Bq/g for uranium and thorium series radionuclides and 10 Bq/g for $^{40}K$ are proposed as generic clearance levels for most situations.

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[2] Amenability to control is a relative concept; it is a matter of practicability and implies recognition of the cost of exercising regulatory control and the net benefit to be gained by so doing.

TABLE 1. THE ASSUMPTIONS ASSOCIATED WITH THE CONCEPTS OF EXCLUSION, EXEMPTION AND CLEARANCE [11, 12]

| Concept | Assumption |
|---|---|
| Exclusion | Amenability to control the exposure |
| Exemption | Exposure associated with trivial risk or optimum option of protection, irrespective of the associated dose |
| Clearance | Exposure associated with trivial risk, and regulatory control of the source or material would yield no net benefit |

## 2.4. IMPLICATIONS OF CLASSIFICATION OF NORM WASTE AS RADIOACTIVE WASTE

Despite NORM being considered as radioactive material upon exceedance of the generic clearance levels, NORM waste might or might not be classified as radioactive waste depending on the country legislation. Article 3.2 of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (later referred to as the Joint Convention) [15] indicates that:

> "This Convention shall also apply to the safety of radioactive waste management when the radioactive waste results from civilian applications". However, this Convention shall not apply to waste that contains only naturally occurring radioactive materials and that does not originate from the nuclear fuel cycle, unless it constitutes a disused sealed source or it is declared as radioactive waste for the purposes of this Convention by the Contracting Party".

Therefore, the classification of NORM waste as radioactive waste may imply different consequences that, for some regulatory regimes, could turn the management of NORM waste into an unnecessarily more complex issue.

As an illustration, in Brazil, Regulatory Requirement NN 8.01 [16] establishes that NORM waste is classified as radioactive waste. In this context, the final destination of radioactive waste (i.e. disposal) is the responsibility of the Brazilian Nuclear Energy Commission (CNEN), implying that no private entity can oversee the disposal of radioactive waste. This fact causes severe constraints in the availability of disposal options for NORM waste in the country, where exportation of these materials is the only currently available option for disposal.

Within the European Union, roughly 50% of countries define NORM waste as radioactive in their legislation [17]. For those countries, the 2011/70/Euratom directive on the responsible and safe management of spent fuel and radioactive waste [18] is fully applicable, whereas it is not enforceable for those countries that do not define NORM waste as radioactive.

The decision on whether to define NORM waste as radioactive waste needs to account for the prevailing legislative framework and — under both scenarios — the extent to which this framework might favour the provision of optimal treatment and disposal solutions. Consideration also needs to be given to the situation in neighbouring countries and the potential impact of the decision on the import or export of NORM waste, while observing the principles of responsible management and environmental justice.

International harmonization, as demonstrated above, is difficult to achieve, and because of that some challenges could be presented to some countries. As an example, NORM residues that are generated in country A, where they are not classified as radioactive waste, might be considered as such in country B. As a result, NORM residue generators and potential consumers of these residues could be faced with the challenge of restricting themselves to national markets, avoiding the administrative and judicial costs or risks of trading with markets that give different, and in some cases unclear, status to these materials. This can cause unwanted consequences, such as the loss of opportunities to extract value from residues by valorization.

With these inputs in mind, it becomes clear that a fundamental point of the national policy on the management of NORM residues is to define whether a NORM residue, once classified as NORM waste, will be regulated as a radioactive waste, taking into consideration the body of regulation pertaining to radioactive waste, including provisions on disposal, valorization and transboundary movement.

## 2.5. SUSTAINABILITY AND WASTE MANAGEMENT HIERARCHY

In 1987, the United Nations Brundtland Commission defined sustainability as “meeting the needs of the present without compromising the ability of future generations to meet their own needs” [19]. Today, although the sustainability paradigm has been embraced by many governments worldwide and in many sectors of society, the increasing threat of climate change indicates the need for more concrete efforts. One of the key areas where those efforts need to be reinforced is sustainable waste management, which stands as a critical component in achieving the sustainability paradigm. The waste management hierarchy offers a basis for implementation.

For NORM residues, the residue management hierarchy and the valorization of residues in the context of the circular economy could be considered fundamental aspects to be embedded in the national policy. This hierarchy (shown in Fig. 2) enables and encourages residue generators to avoid the production of residues and to manage unavoidably generated waste in the most environmentally sustainable manner. The circular economy, on the other hand, establishes that, as much as possible, everything is reused, remanufactured or, as a last resort, recycled back into a raw material or used as a source of energy so that a zero waste situation will be achieved (as discussed in Section 2.6).

In terms of residue management hierarchy, waste prevention is the first step in the hierarchy and can be achieved, for example, by means of better design of processes (such as the replacement of piping materials with others less likely to develop deposits of inorganic scales or use of scale inhibitors).

Residue minimization or reduction is possible by means of different approaches that can include:

- Separating out residues where they are mixed or before they can become mixed;
- Reducing the activity levels of residues through decontamination (accounting for the impact of secondary waste generation);
- Reducing volume (by compaction or incineration) to ensure best use of disposal capacity;
- Improving the characterization of residues such that, upon compliance with the clearance levels, they can be cleared/exempted from regulatory control.

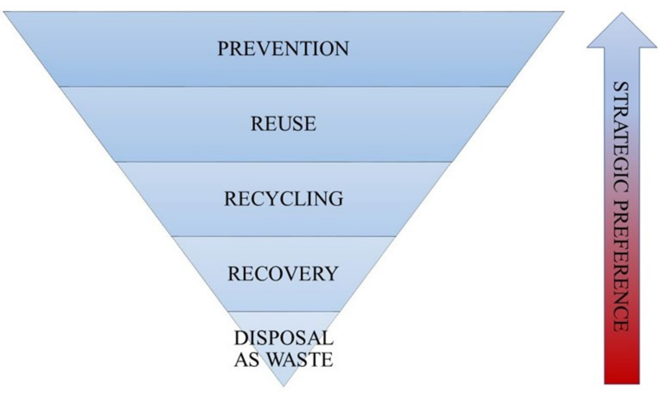


*FIG. 2. The residue management hierarchy pyramid [9].*

Residue reuse involves "the use of an item again after it has been used before. *Reuse* includes conventional *reuse,* in which an item is used again to perform the same functions, and *reuse* in which an item is used again to perform a different function" [1]. Reuse defers waste production and extends the life of resources.

Residue recycling is the process of converting residue materials into new products [1]. It "reduces the wastage of useful materials as well as the use of raw materials…" [1], consequently reducing the dependence on natural resources.

Material or energy recovery involves the dismantling, sorting and conversion of non-recyclable residues to separate out useful materials or to produce usable heat, electricity or fuel through a variety of processes. Examples pertaining to NORM are the extraction of Pb and Sn from tin mining legacy waste or the use of filter cakes from $TiO_2$ production as secondary fuel.

Finally, the disposal of residues as waste has to be used with appropriate discretion as a last resort. Ensuring that there is enough disposal capacity in the country is critical in any national P&S on residue management, as discussed in Section 3.6.

## 2.6. CIRCULAR ECONOMY PRINCIPLES — TOWARDS ZERO WASTE

In the section above, the principle of sustainability was presented based on the residue management hierarchy. This approach leads to the paradigm of the circular economy, which has its roots in the '3R framework' (reduce, reuse and recycle) [20].

The circular economy can be seen as a pathway towards sustainability, as it prescribes that waste is to be not only prevented or minimized, but also cycled back into the production process. Some authors [21] support the thesis that the circular economy has to be totally integrated with sustainable development. To that end, it is suggested that a deep reconsideration of the circular economy is needed, broadening the scope from closed loop recycling and short term economic gains in favour of a revised and eventually transformed economy. This can provide some disciplined access to resources to maintain or enhance social well-being and environmental quality.

A considerable amount of work has been carried out to investigate the barriers to the circular economy. However, few academic studies have been produced about policies that could accelerate the transition from a linear economy towards a circular economy [22]. Eventually, such policies take the form of a "…mix to stimulate resource efficiency, emphasizing both primary and supplementary instruments (e.g. materials taxes, extended producer responsibility and technical requirements)" [22].

An example of the adoption of policies supporting the circular economy can be seen in the European Commission Circular Economy Action Plan [23]. This plan "provides a future-oriented agenda for achieving a cleaner and more competitive Europe in co-creation with economic actors, consumers, citizens and civil society organisations" [23].

There is wide agreement that the principles of sustainability and the circular economy would need to be embedded in the national P&S for NORM residues management, as highlighted in 2020 in the IAEA International Conference on the Management of Naturally Occurring Radioactive Material (NORM) in Industry [24]. In a recent workshop organized by the Forum for Nuclear Cooperation in Asia (FNCA), it was recognized that minimization of the volume of NORM waste could be achieved by taking into consideration the circular economy approach [25]. It was also acknowledged that the success of this model would depend on concerted efforts by the regulator, the industry sector and the public in general. In terms of public acceptance, communication is key to demonstrate how NORM residues can be safely valorized within the scope of the circular economy. Open and transparent communication about the risks due to radioactivity from natural sources is essential but challenging, as the level of scientific, technological, engineering and mathematical (STEM) knowledge and understanding of the public may be extremely variable.

A clear example of a NORM residue entering the circular economy is phosphogypsum. The management of this residue presents challenges and opportunities and has become an industry priority [26]. Phosphogypsum management encompasses many strategic issues, such as materials reuse and recycling, safety and sustainability, life cycle analysis, technical opportunities and new business models, as well as interested party engagement and social licensing.

Two important steps, as shown in Fig. 3, are to be observed in the consideration of phosphogypsum within the boundaries of the circular economy. These include a pre-circular, 'transitional' model, in which, as demonstrated above, the residue hierarchy could serve as a bridge between the linear and the circular economy; and a second step in which the material remains within the boundaries of the system and does not leave as waste.

One industry to which circularity is particularly well suited is metal ore mining and processing. Overall, metals are infinitely recyclable, and advances in hydrometallurgical and electrochemical processes are enabling the recovery of critical elements from industrial and mining waste streams. The so-called critical elements play a key role in the transition to clean energy, as energy systems that are supported by clean energy technologies differ to a great extent from those powered by traditional hydrocarbon resources. Just for the sake of

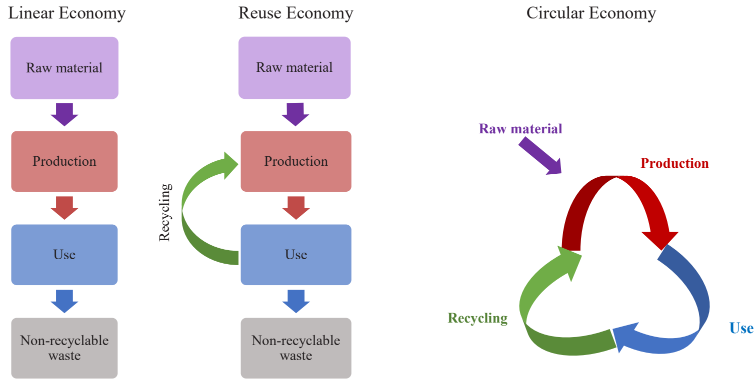


*FIG. 3. Circular meta-scheme of the transition from a linear economy to a reuse economy and then a circular economy.*

comparison, the construction of solar photovoltaic plants, wind farms and even electric vehicles demand much greater amounts of minerals than their fossil fuel based equivalents. Furthermore, "Lithium, nickel, cobalt, manganese and graphite are essential to battery performance, longevity and energy density. Rare earth elements are essential for the permanent magnets that are crucial in wind turbines and EV (electric) motors. Electricity networks need a huge amount of copper and aluminium, with copper being a cornerstone of all electricity-related technologies" [27]. (Re)mining or (re)processing of tailings from NORM industries has increasingly become a viable source of supply for these critical elements, contributing to sustainability, but at the same time this can also pose environmental challenges.

## 3. ELEMENTS OF A NATIONAL POLICY

A national policy has to reflect the country's priorities and be tailored to the country's circumstances and political, social and legal structures, while accounting for the human and financial resources available or that can be made available to support the policy. It also needs to be consistent with the relevant international instruments or agreements in place and with other related policies. This includes, for example, those dealing with hazardous materials or the decommissioning of industrial facilities.

Although there is no single model for developing a successful national policy for the life cycle management of NORM residues, some common elements may be identified that need to be considered. These elements are discussed in the following subsections.

## 3.1. ASSIGNMENT OF RESPONSIBILITIES

A starting point when establishing the national policy for NORM residues management is the assignment of responsibilities at the national level. Compared to radioactive waste, governance in NORM residues management is particularly challenging because of the wide diversity of actors involved, including national, regional and local governments that comprise, but are not restricted to, radiation safety and environmental authorities and the relevant regulatory bodies.

In line with Ref. [4], the core regulatory functions that need to be covered with regard to ionizing radiation are:

- Development and/or provision of regulations and guides;
- Notification and/or authorization of NORM involving practices;
- Review and assessment of facilities and activities;
- Inspection of facilities and activities;
- Enforcement of regulatory requirements;
- Provision of information to, and consultation with, parties affected by its decisions and, as appropriate, the public and other interested parties.

In some jurisdictions, regulation of NORM residues occurs primarily at the state/regional level (as opposed to the national level), which might be challenging when developing a national level policy. On the other hand, in many countries more than one agency has regulatory oversight of aspects related to the management of NORM residues. In some cases, regulatory changes or revision of organizations' mandates and missions might be needed to ensure effective oversight during the implementation phase.

Adding further complexity, NORM contaminated legacy sites might be regulated by authorities different to those responsible for ensuring radiation safety related to the management of NORM residues. In some circumstances, this situation might lead to conflicting decisions and even legal uncertainty. In this multiagency setting, coordination agreements or memorandums of understanding among the organizations involved are essential to ensure a consistent and harmonized approach as well as to pool scattered resources, competencies and powers.

On the other hand, the national legal framework needs to ensure — within the scope of the 'polluter pays' principle[3] — that the responsibility for NORM waste rests ultimately with the producers of the waste and that residues generators seek appropriate guidance and administrative permissions from regulators before taking decisions on NORM residues management. Moreover, the role of operators in meeting environmental targets by implementing 'best available techniques'[4] (when defined for the sector) [28, 29] can be key to a sound waste management approach.

Regarding treatment, storage and disposal, although the role of government is clear in terms of creating an effective regulatory and planning environment, different approaches could be taken in terms of who is responsible for providing such solutions. That responsibility might be assumed either by the government, by private companies or by some combination of the two. The implications of this decision need to be assessed. For example, if private companies operate NORM waste treatment and/or disposal facilities, decisions about investment in new facilities or changes to the operation of existing facilities will be commercial decisions influenced by information on likely future waste arising or liability considerations, as well as by the regulatory environment.

The national policy needs to clearly identify all actors concerned and allocate responsibilities to each of them, or at least provide a framework that enables a proper coordination of activities.

## 3.2. POLICY INSTRUMENTS

The first response by governments to a newly identified policy issue is often to regulate the related activities. Regulation is necessarily a key enabler of the national policy for NORM residues management. Nevertheless, traditional regulatory approaches (usually referred to as 'command and control') have been progressively substituted by other more effective and complex models. The use of alternative policy instruments can not only improve regulatory compliance but also contribute to reaching the intended outcomes at lower cost; for example, by fostering employment and enterprise development opportunities.

Most policy instruments can be categorized as one of four types: regulation; voluntary agreements; economic instruments; and information and education.

[3] Directive 2008/98/EC on waste introduced the 'polluter pays' principle and the 'extended producer responsibility'.

[4] 'Best available techniques' means the latest stage of development of processes, facilities or methods of operation that is practicable and suitable to limit waste generation and disposal.

Regulation pertaining to NORM residues management is further developed in Section 3.4. The three other types are described below.

The first type of instrument refers to voluntary agreements that can be established among various parties, usually the government and private companies, or undertaken by an industry association to introduce particular measures. They are largely the outcome of negotiations among representative social partner organizations, involving, where appropriate, the relevant authorities or public agencies.

Often, regulators promote this type of instrument when they lack the political support, technical means or institutional capacity needed for mandatory policies. For the private sector, motivations to enrol in voluntary agreements can include taking advantage of subsidies or technical assistance offered to participants or improving their environmental performance, thus enhancing company image.

The so-called Spanish Protocol [30] contains a successful example of these kinds of instruments, which served as inspiration for the IAEA “Metal Recycling Code” [31]. This protocol was an agreement reached voluntarily by the Government, industry, trade unions, and the Nuclear Safety Council of Spain (CSN), which is the nation’s regulating agency. The strategy was devised due to the 1998 Acerinox incident, in which a steel production facility’s undetected melting of a cesium-137 source occurred. The purpose of the Spanish Protocol is to detect radioactive materials and safely manage those that are found in order to avert such incidents.

In 2009 around 50% of such detections correspond to NORM found primarily in imported shipments of scrap metal, proving the protocol to be a useful monitoring tool beyond the purpose for which it was conceived [32].

The second type of instrument is the economic instrument. These are essential in waste management to make systems more efficient and to internalize the costs of waste management, so that they are borne by those who generate the waste. To achieve this, taxes are applied in most countries on the interim storage, landfill disposal or incineration of industrial (inert, non-hazardous and hazardous) and radioactive waste. Such taxes are not only conceived to cover the cost of the service but are also widely applied as incentives for companies to reduce and recycle waste, improving the circularity of the economy.

Economic instruments also include subsidies, which are often used when certain industries face barriers to entry into the desired management system. These subsidies can be direct or take the form of organizational and technical assistance, tax reductions, etc. An example of this is the subsidization of controlled industrial landfills to help them comply with the requirements needed for them to accept NORM waste, thus providing viable disposal routes. Subsidies could be dedicated, for instance, to the acquisition or operation of portal detectors.

Other examples of economic instruments would be developing business support schemes to promote the deployment of new reuse or recycling technologies or funding initiatives to support R&D, as innovation is essential to fostering circular economy models. For example, under European Cooperation in Science and Technology (COST), a funding organization for research and innovation networks in the European Union, actions are supported to connect research initiatives across Europe and beyond and enable researchers and innovators to develop their ideas by sharing them with their peers. The COST Network 'NORM4Building' [33] for the reuse of NORM containing residues in building materials, led by the University of Hasselt. The aim of NORM4Building was to stimulate research on the reuse of residues containing NORM in tailor-made building materials in the construction sector, while considering the impact on both external gamma exposure of building occupants and indoor air quality.

Finally, information and education instruments, which are often characterized as 'light handed' instruments because of the lesser degree of direct government involvement, are more limited than other instruments. However, in the context of the management of NORM residues, information and education through open and transparent communication are critical success factors. They are critical success factors on the one hand, because the success of the policy partly relies on changing the attitudes of many of the interested parties involved; while on the other hand, because an appropriate level of re-education and (re)training would have to be ensured for the participating agents (government, politicians, regulators, senior management, waste management technicians, radiation protection experts and officers, etc.) to perform competently.

From a broader perspective, communicating radiation information to the public in an open, transparent and emphatic manner will help rationalize public risk perception and attitudes, making it possible to start a mature and informed debate on the issues and solutions, which is key to a meaningful engagement. Furthermore, to foster openness and transparency, governments can require companies to provide greater information to the public, or the government can provide the information itself. For instance, annual inventory reports on NORM waste generation can be made public, disclosing information at the sector or facility level.

Regarding education and training, the role of the government is to promote and support industry and academia in developing training courses and capacity building programmes that allow recipients to acquire and maintain new competencies. Although existing education and training programmes in the country related to nuclear, radiation or waste safety are fundamental to building capacity, it needs to be recognized that the specificities of NORM management call for a well tailored, multidisciplinary, integrated approach.

Beyond technical competence, all the organizations involved or affected by the policy need to create an organizational culture that works both to achieve safety day by day and to promote and encourage compliance with the UN SDGs. In some industries, such as mining or oil and gas, a clear leadership is essential for process safety. In these industries, the Organisation for Economic Co-operation and Development (OECD) identifies four key elements of corporate governance [34]:

— Leadership and culture;
— Risk awareness;
— Information;
— Competence.

Ideally, the governance structure also needs to take into account the environmental and social performance of the company, putting the SDGs at the core by embedding sustainability and accountability throughout the supply chain [35].

## 3.3. REGULATORY FRAMEWORK

A country's ability to control radioactive material in its territory depends largely on its legislative and regulatory system, which has to provide for the oversight and control of activities involving its management. Detailed requirements to achieve the internationally agreed fundamental safety objective to protect people and the environment from harmful effects of ionizing radiation are established in GSR Part 3 [14]. In particular, the regulatory framework for the safe management of NORM residues can be based on these safety requirements.

GSR Part 3 establishes that [14]:

> "**The government shall ensure that existing exposure situations that have been identified are evaluated to determine which occupational exposures and public exposures are of concern from the point of view of radiation protection.**"

Nevertheless, GSR Part 3 also specifies that (footnote 17 is omitted in quote) [14]:

> "Exposure due to natural sources is, in general, considered an existing exposure situation and is subject to the requirements in Section 5.

However, the relevant requirements in Section 3 for planned exposure situations apply to:

(a) Exposure due to material in any practice...where the activity concentration in the material of any radionuclide in the uranium decay chain or the thorium decay chain is greater than 1 Bq/g or the activity concentration of $^{40}K$ is greater than 10 Bq/g".

On the other hand, for NORM residues that exist as residual radioactive material in the environment, the requirements for existing exposure situations apply irrespective of the activity concentrations [14].

Industrial practices generating residues with activity concentrations above the values mentioned in the above paragraph, or where NORM residues are managed (including reuse, recycling, disposal and long term management), might be subject to some form of regulatory control as it applies to planned exposure situations. The control could vary from notification to authorization by registration or licensing, in accordance with a graded approach commensurate with the associated radiation risk. Recommendations specific to NORM residues management are provided in SSG No. 60 [5]. This safety guide defines the responsibilities of the government and of the regulatory body and the operating organizations and provides guidance on achieving best practice that needs to be implemented to the degree appropriate to the level of risk.

Moreover, if a given NORM residue is declared to be radioactive waste by the regulatory body, the Joint Convention applies, as do the safety principles for radioactive waste management set out in the IAEA Safety Fundamentals. These require governments to 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) [15].

Governments have also to ensure that arrangements are implemented for the safe long term management of radioactive waste. IAEA Safety Standards Series No. SSR-5 [36] defines safety requirements relating to the disposal of radioactive waste of all types. These include not only waste from ongoing facilities but also radioactive waste arising from the remediation of radiologically contaminated land (GSR Part 3, Requirement 49) [14]. Moreover, Article 27 of the Joint Convention sets out the obligations of contracting parties regarding the control of transboundary movement of radioactive waste [15].

Countries where NORM residues are not defined as radioactive waste, or where only NORM residues meeting certain conditions are declared as such, need to ensure that the regulatory framework pertaining to NORM residues adequately covers those aspects (including conditions on imports/exports) to provide an equivalent level of radiation safety.

It is worth noting that, notwithstanding radiation safety aspects, NORM residue could also be subjected to industrial waste management legislation, including, when applicable, legislation on hazardous waste. An industrial waste is classified as hazardous waste if it is listed as such or meets certain characteristics. In Europe, for example, the classification of waste is based on:

— The European List of Waste (Commission Decision 2000/532/EC) [37];
— Annex III to Directive 2008/98/EC [9].

Consistency and, when beneficial, integration of the regulatory framework for radiation and non-radiation safety aspects needs to be a key aspect of the policy on NORM residues management.

## 3.4. NATIONAL NORM RESIDUE INVENTORY

An indicative inventory of the types and amounts of existing and future NORM residue in the country needs to be made available for those involved in P&S development. This inventory needs to account for:

— NORM residue arising from the normal operation of NORM industrial facilities in the country;
— NORM waste from decommissioning of abandoned and operating facilities as they reach the end of their productive life;
— NORM waste arising from the remediation of contaminated land;
— Imports of NORM residues, when allowed.

The inventory is a fundamental tool for the development, implementation and review of the national P&S for the management of NORM residues, requiring different levels of detail at the various stages of the process.

## 3.5. INFRASTRUCTURE REQUIREMENTS

Infrastructure capacity (including treatment/valorization, storage, predisposal and disposal activities) is essential for an effective management of NORM residues. At the early phase of policy development, the available information might not support a detailed forecast of infrastructure needs. Nevertheless, even in the absence of solid data or estimates, consideration of the available infrastructure in the country, as well as the institutional and private capacity to manage NORM residues, needs to be made at this early stage to set realistic policy goals. A more detailed analysis will be warranted of the NORM infrastructure capacity when developing the national strategy, as discussed in Section 4.2.

Because treatment options are usually specific to each residue stream, the associated infrastructure needs to be analysed considering relevant NORM residue streams in the country. It should be considered whether the country already has a well established treatment or recycling industry that could absorb the NORM residues generated in the country, or whether there is a market demand for them abroad. In the latter case, international conventions or agreements should be observed about the transboundary movement of materials that might be considered as radioactive material, as well as, when appropriate, about hazardous and radioactive waste. Sustainability (carbon footprint) considerations, on the other hand, favour solutions in locations as close as possible to the point of generation, although this might not often be viable when dealing with particular types of residues.

As for disposal, very low level or low level waste repositories are used in some countries to dispose of NORM waste. Nevertheless, these facilities often have constraints on the disposal of long lived radionuclides, and for this reason, they might not be suitable options for the long term disposal of NORM waste, which may contain long lived isotopes from the uranium and/or thorium series radionuclides or $^{40}K$.

As an alternative, many countries have made provisions to allow the disposal of NORM waste in designated controlled landfills (licensed for hazardous or non-hazardous waste) provided that (a) certain limits of specific activity in the shipment and percentage total activity at the landfill are not exceeded and (b) the facility remains subject to several radiation control, monitoring and reporting measures. Such options can provide economically attractive disposal routes while still ensuring adequate protection of society, human health and the environment.

Several countries with substantial NORM waste generation coming from the oil and gas industry, such as Norway, the United Arab Emirates and the United Kingdom, have licensed specific NORM waste repositories. These typically include facilities for cutting, descaling/decontamination and conditioning of the waste. The suitability of the disposal route and the associated predisposal steps is also a function of the waste activity concentration, its potential classification as hazardous waste and its organic content.

## 3.6. FUNDING

The national policy for NORM residues management will need to set out arrangements to identify which party or organization(s) will shoulder the costs related to the entire life cycle management of NORM residues for which either disposal is the only viable alternative or low market prices do not cover recycling costs.

According to the polluter pays principle, the waste generator is generally to be made financially responsible for ensuring that generated NORM waste is properly and safely managed, thus bearing the costs related to the operations. These costs have to account for provisions for the long term management of these wastes, considering the long half-lives of the radionuclides involved (uranium series and thorium series long lived isotopes and $^{40}K$). Moreover, statutory enactment of the polluter pays principle may be a useful driver for companies trying to avoid disposal and instead encourage valorization solutions.

The legal framework has to enforce financial assurance from the residue generators that they will be able to fulfil their NORM management responsibilities, even in the case of unanticipated events such as an accident, bankruptcy, or other circumstances that force an early end to operations or some other unanticipated occurrence. This guarantee is typically given in the form of a bond or bank guarantee, which increases over time in proportion to the amount of residue and contamination created by the site. In addition to guaranteeing that the government will not be left with a financial burden down the road, the financial guarantee permits the construction of new industrial facilities. The financial guarantee also acts as a deterrent for the business to finish its operations safely and gives the public confidence that the environment will be preserved without adding to the burden of taxes on society [2].

The government is typically in charge of any post-closure institutional controls that might be required to ensure the secure long-term management of NORM waste; however, the waste generator may need to make advance funding arrangements for this, in which case the amount of the financial guarantee would need to take that into account. The financial guarantee's amount must be updated frequently and modified as needed [2].

In addition to the above mentioned provisions, the OECD reviews have shown that governments have played a key role in many countries by providing support for waste management investments. governments rely on several mechanisms, including grants, loans and tax exemptions that support investments made by businesses and specialized producers. To finance such mechanisms, several Member States of the OECD have used funds whose revenues come from environmental charges and taxes [38]. These same models are applicable to enable the launching of the national P&S for the management of NORM residues.

On the other hand, sustainability and circular economy models have been typically promoted by governments by alignment of taxes on primary raw materials, together with general or specific taxes on products, decreasing with increased sustainability. Other financial instruments with that aim are referred to in Section 3.3 above.

### 3.7. COMMUNICATION AND PARTICIPATION

The Aarhus Convention [39] entered into force on 30 October 2001 and was ratified by 47 countries worldwide. It establishes several rights of the public regarding the environment, including:

- The right of everyone to receive environmental information that is held by public authorities ('access to environmental information');
- The right to participate in environmental decision making;
- The right to review procedures to challenge public decisions that have been made without respecting the two aforementioned rights or environmental law in general.

Specific to radioactive waste, the Preamble of the Joint Convention [15] recognizes the importance of informing the public on issues regarding the safety of spent fuel and radioactive waste management. Consultation with interested parties is also addressed, in the context of NORM residues management, in different IAEA publications [2, 3].

But beyond binding information and consultation obligations set up in international agreements, which are, in turn, usually enacted in national legislations, participatory policy making can achieve better outcomes by facilitating the inclusion of individuals or groups in policy design. Although it takes longer and is costlier than traditional approaches, compared to cases where policy development was carried out by government agencies alone, the advantages of open and inclusive policy making are manifold. They include [40]:

- Providing new inputs, innovative ideas and evidence about problems and solutions;
- Ensuring that policies and services address the real needs of citizens;
- Strengthening trust, social cohesion and capital through its inclusive approach.

To achieve those benefits, the national policy on NORM residues management needs to establish mechanisms to involve interested parties in the formulation of the approaches that will be used in the management of the subsequently generated

NORM waste (and potentially other approaches in the scope of the residue management hierarchy and eventually in the scope of the circular economy), not only at the national level but also locally. To achieve this, a detailed work plan needs to be prepared and time, staff and budget set aside for joint efforts.

When identifying and engaging with interested parties, it is important to consider that the presence of radioactivity in NORM residues might be a cause of fear and uncertainty for people living near facilities where NORM is produced or disposed of. The overall decision making process and the resulting management solutions (including those approaches that are part of the residue management hierarchy) needs to be clear, transparent and participatory, as they will be of interest to a wide range of stakeholders, including the public and especially local communities. Interested parties constitute a highly heterogeneous group with varying levels of knowledge and experience. Ideally, they will be all involved in the decision making process, with the aim of achieving a shared understanding of the situation and its implications for all parties.

## 3.8. HORIZONTAL POLICY COORDINATION

Ensuring safe and sustainable management of NORM residues requires the integration of many different aspects that include the radiological and non-radiological properties of NORM residues. Even for countries where a comprehensive stand-alone P&S is developed for the management of NORM residues, it is foreseeable that there would be multiple interfaces with other related policy areas that could have a positive or negative impact on achieving policy goals. The multifaceted nature of NORM residues requires that the national policy on the subsequently generated NORM waste management be coordinated with several other policies and strategies, such as the policy on the management of contaminated land or the radioactive waste management policy. Other policies, such as those on the circular economy or on environmental pollution control, which would typically exist in most countries, may also have an impact.

This situation creates risks of inconsistencies and incoherence. However, when potential synergies among interconnected policies are identified, they might be exploited for better use of resources and outcomes. Therefore, to promulgate a coherent life cycle management of NORM residues, policy makers should:

— Actively seek to identify other related policies and take joint action to correct existing policy misalignments and achieve coherence;
— Explore the feasibility and potential benefits of policy integration and, when advantageous, promote a macro level P&S as well as organizational changes.

# 4. NATIONAL STRATEGY DEVELOPMENT CYCLE

The national strategy for the management of NORM residues needs to articulate how policy goals and objectives may be achieved. While every country faces challenges shaped by a distinct production profile and socioeconomic situation, this section presents a general framework aimed at assisting all those involved in the development, implementation and review of the national NORM residues management strategies, regardless of country circumstances. As already mentioned, specific guidance on the valorization of residues, particularly in the context of the circular economy, will be provided in another publication.

## 4.1. INITIAL CONSIDERATIONS

The ultimate objective of a comprehensive strategy for NORM residues is to ensure that secure, sustainable and resilient NORM management options are available, preferably in the country of origin. Ambitious strategies have a long term horizon and are conceived as an iterative process rather than a linear one, consisting of the following phases:

— Development;
— Implementation;
— Review and update.

A series of steps are proposed within each of the three phases that need to be followed in developing a national strategy on NORM residues management. These are shown in Fig. 4 and elaborated in the following subsections. It should be emphasized that consultation and engagement with different interested parties need to be sustained throughout the overall process.

## 4.2. DEVELOPING THE STRATEGY

According to UNEP's Guidelines for National Waste Management Strategies, a national residue management strategy may consist of [41]:

“• An ambitious, overall framework and goal for waste generation and management in the country;
• A list of priority waste streams and issues for the country;


*FIG. 4. National NORM residues strategy cycle.*

- An action plan for each waste stream or issue, comprising one or more targets, policy actions on prevention, materials recovery and management;
- Accurate cost estimations for each action plan;
- Clearly allocated responsibilities for giving effect to the actions identified;
- A coordinated plan for building reliable data and information about waste in the country;
- Plans for review (including indicators to measure progress) and revision of the strategy on a regular basis and as developments require."

Whereas the national NORM residues management strategy can cover all these items, its scope as well as the allocated efforts and resources will differ significantly depending on the country's NORM residue inventory. Some countries are responsible for relatively small volumes of NORM residue, while others have comparatively large or complex inventories derived from several different sectors such as oil and gas extraction, metal mining and processing or rare earth extraction.

Although strategies might be developed at the regional level, there are several benefits in adopting a national strategy, such as:

— Increased political and social visibility;

— The possibility to mobilize more human and technical resources;
— More rational, coordinated and efficient planning of NORM residues management routes, including disposal infrastructures as necessary.

In addition, specific strategies — which have to comply with the national level strategy — could be developed by other agents, such as the waste management organization (which may be either a government or private entity) or the waste owners.

Responsibility for the formulation of the overarching strategy at the national level lies with the government, which will usually entrust the development of the national strategy for NORM residues management to the administration or body(s) having the statutory powers on the regulation and/or oversight of the life cycle management of NORM residues.

The steps to be followed by this leading agency in the first phase of the strategy development cycle are described below.

#### 4.2.1. Engaging with interested parties

The success of the national strategy on the life cycle management of NORM residues relies on a leading agent being able to unite and exploit the capacities and efforts of all the relevant parties. Interested parties might include:

— Other government agencies or regulatory bodies with responsibilities in radioactive or hazardous waste related matters;
— Regional and local authorities;
— The operators/managers of NORM industrial facilities or activities generating NORM residues;
— Service providers;
— The informal waste sector (in low and middle income countries, e.g. artisanal mining);
— Citizens;
— Non-governmental organizations;
— Academics and researchers.

As the number of interested parties can be quite large and their backgrounds, roles and capacities very diverse, it is important to find ways to engage with each of them to maximize their ability to provide the necessary relevant input.

These types of actions need to be carefully planned and maintained over time, to maximize benefits and gain broader support and commitment. These activities might be overseen by, for example, an ad hoc coordination committee composed of representatives of each of the main interested parties.

The coordination committee might later set task forces into action focusing on specific aspects of the strategy. Moreover, the coordination committee may eventually become a standing body in charge of the follow-up and update of the national strategy on NORM residues.

To engage with a wider audience, a consultation can be launched. Face to face interviews might be used to enable interviewees to shape their contributions and later facilitate a general debate. Deliberation can take place through workshops, public hearings and, when needed, bilateral meetings.

Once the draft strategy document has been prepared, public consultations are typically established (for example, through online platforms) to ensure that all views have been properly considered before strategy approval. In some jurisdictions, this public consultation process is enacted by law or regulations as a mandatory step in strategy development.

### 4.2.2. Developing the inventory

The famous quote attributed to management expert P. Drucker, "What gets measured, gets managed", is well suited to the residue management context. A robust and efficient market requires good data and information about current and projected NORM residue generation at the national level. In more specific terms, a national NORM residue inventory would serve the following functions [42]:

- Allow (at the governmental level) for the development of strategies for managing NORM residue and assist regulatory bodies in their functions.
- Assist the supply chain organizations that process waste materials and need data to support the planning, operation and performance of their disposal facilities.
- Provide elements to waste planners (i.e. when residues are classified as waste) who are responsible for ensuring that management facilities meet local and national needs.
- Give researchers and academics solid ground to support the development of innovative technologies and processes for managing NORM residue.
- Allow the relevant stakeholders, including members of the public, to become more knowledgeable and informed about NORM residue.

Consequently, the national level NORM residue inventory represents a basic instrument to support the development of a national P&S.

The specific role of this inventory depends on the stage of development of the NORM residues management strategy. At an early stage, the inventory is often created using estimates of NORM residue generation, typically based on:

- A review of current residue management practices in the country;
- The identification of operating NORM related facilities;
- A limited number of ad hoc investigations conducted in specific facility types to assess volumes of NORM residue produced.

In this early context, the inventory is aimed at identifying the main producers, the most relevant streams and potential service providers, as well as assessing investment needs.

For countries that have not previously regulated NORM industries, or when a system for collecting site specific data from generators is not yet in place, such ad hoc studies and estimates could be the only way of producing the information basis for setting priorities and for planning the management infrastructure.

In a more advanced stage, when a national system is in place (including regulation on NORM residue and a notification or authorization system for producers and managers), the inventory is fed from the data directly provided by the regulated facilities and from regulatory inspections. This more advanced type of national inventory is typically updated annually.

NORM waste resulting from NORM industrial facility decommissioning activities and from the remediation of contaminated sites also need to be accounted for in the inventory, which might be a major challenge.

Globally, an increasing amount of NORM industrial facility infrastructure is either reaching end-of-life or undergoing ageing and life extension (ALE) and will eventually need to be decommissioned, with the offshore oil and gas industry being the main potential source of NORM waste. In some countries, abandoned metal or phosphate processing facilities might also represent a substantial contribution to the NORM decommissioning waste to be managed. As for the remediation of NORM contaminated sites, in situ or on-site remediation solutions can be preferred in terms of sustainability over off-site waste disposal. However, there might be sensitive environments from which waste needs to be removed to mitigate environmental damage and disposed of off-site in specifically built infrastructures.

For inventory purposes, the following type of information is typically collected from each residue generator:

- The type of residue;
- Chemical and physical properties;
- Radioactive waste classification (when appropriate);

— Average and maximum activities of the residue streams;
— Annual and lifetime arisings;
— Whether there will be any hazardous materials associated with the residue;
— The major radionuclides associated with the residue.

#### 4.2.3. Conducting a situation and gap analysis

The inventory provides key information to develop the national strategy for NORM residues. However, in addition, there are several key questions that need to be addressed to acquire the necessary knowledge and information for establishing the strategy, such as:

— What is the current regulatory framework on the life cycle management of NORM residues? Is it comprehensive (covering provisions on exemption, clearance, recycling, recovery, disposal) and fit for purpose?
— Is there an authorization system in place for residues generators and managers? Do they have periodical reporting obligations?
— Are there adequate (i.e. both suitable and sufficient) enforcement mechanisms to ensure compliance?
— What technologies are internationally applicable for treatment, recycling and recovery of the different NORM residue streams? Are they available, or can they be made available, in the country?
— Which of the infrastructures existing in the country could potentially be used for treatment, recycling or disposal of the different NORM residue streams?
— Given the volume and composition of the different residue streams to be managed in the country and the geographical distribution of the NORM residue producing facilities, what are the current infrastructure capacity needs?
— What are the available capacities in the country in terms of skilled personnel, measurement laboratories, etc.?
— What funds are available to support the establishment of the strategy?
— Is there enough information on current interest parties’ perceptions? Is education or a change of attitude needed to enable a constructive dialogue?

In addition, a review of the international situation regarding the life cycle management of NORM residues, with a special focus on countries with similar socioeconomic circumstances and industrial profiles, can also be undertaken in search of applicable solutions and best practices.

The result of the analysis provides a clear picture of the country's prevailing situation and identifies the gaps between the current state and the optimized, yet attainable future defined by the policy objectives.

#### 4.2.4. Choosing policy instruments

Section 3.3 provides an overview of the different types of policy instruments, namely regulation; economic instruments; voluntary agreements; and information and education.

Regulation on radiation safety is a necessary and key element of a national P&S on NORM residues management. Among the other policy instruments, the national strategy needs to identify which ones will be most effective at achieving policy goals, taking into consideration the different NORM residue streams and their volumes, as well as other elements specific to the country situation, listed in Section 4.2.3.

The selection should be made based on criteria of effectiveness, cost and equity. Very often, the optimal outcome will be obtained by a combination of different instruments.

#### 4.2.5. Drafting the strategy

The national strategy for the life cycle management of NORM residues will cover all types of NORM residues generated throughout the country, as well as, when applicable, imported/exported residues. It will follow an integrated 'cradle to grave' approach over the entire waste life cycle, considering the waste management hierarchy and taking into account aspects related to the collection, storage, transport, predisposal treatment and disposal of NORM waste.

Since managing a given NORM waste stream typically involves a number of strategies to mitigate, reduce, or control related risks, the strategy formulation process must take an optimum approach that takes into account a variety of management choices. Every stage of the NORM residue life cycle requires attention, beginning with avoidance or minimization at the source and continuing through valorization (the preferred option) or pre-redisposal steps (pretreatment, treatment, blending, conditioning, and storage) until the residue is declared waste, at which point disposal takes place [2].

All management alternatives based on proven technology (methods, techniques, equipment, and processes) that can be applied in compliance with the applicable IAEA Safety Standards for each NORM residue stream must be identified. One important factor to take into account while determining the potential solutions is the accessibility of the required infrastructure. The interdependencies between each stage of the NORM residue life cycle, such as planning, building, commissioning,

TABLE 2. ASSESSMENT METHODOLOGIES USED TO SUPPORT SOUND DECISION MAKING IN WASTE MANAGEMENT

| Technique | Advantages |
|---|---|
| Cost–benefit analysis | Provides clarity and is easy to understand for interested parties<br>Fixed evaluation criteria |
| Multi-attribute analysis | Helps build interested party trust and support as they can set evaluation criteria<br>Ability to involve combinations of criteria that can be valued in monetary terms and criteria for which monetary valuations do not exist |
| Life cycle assessment | Quantifies environmental effects such as overall energy consumption or air and water emissions<br>Helps reduce overall environmental impact and costs |

operating, maintaining, and decommissioning NORM-related facilities, are also crucial to take into account. Decisions made at one stage can influence the final result by compromising or eliminating options at a later stage [2].

To optimize the design of the strategy, for each viable option identified, the risks and benefits can be evaluated. Different techniques can be applied to perform this analysis in quantitative terms. Table 2 summarizes the most widely applied methodologies to evaluate and rank waste management options [43, 44].

Regardless of the methods or supporting techniques used in the evaluation of NORM residue management options, the following aspects are typically taken into account in the decision making process:

— Technological considerations, including long term performance and the extent to which the technology is proven and used internationally.
— Health, safety and environmental considerations:
    - Exposures of workers and members of the public (compliance with dose limits and ALARA optimization);
    - Transport safety;
    - Maritime safety;
    - Operational safety;
    - Environmental impact;
    - Generation of secondary waste;
    - Sustainability.
— Social and economic factors:
    - Monetary cost;

- Creation of jobs and business opportunities;
- Perceived risk and societal acceptability;
- For legacy sites, benefit to the community in relation to the 'no action option'.

Based on the previous analysis, key performance indicators (KPIs) and associated targets will constitute a set for each residue stream or for the overall residue inventory. These can be numerical targets, such as the percentage of recycling of all NORM residue generated by a given metal processing industry or the inadvertent NORM residue disposal as waste in non-hazardous waste landfills to be eventually phased out over a given period.

Nevertheless, using numerical targets as a driver is more suitable for nations that already have some experience or expertise. When numerical targets cannot be set because no reliable data on NORM residue generation can be obtained through self-monitoring and compliance monitoring, quality based indicators may be used.

In light of the above considerations, all these elements need to be included in the national NORM residues management strategy document.

## 4.3. IMPLEMENTING THE STRATEGY

Once the strategy development phase is completed and the P&S documents have been drafted, the next phase is implementation of the strategy according to the following steps.

### 4.3.1. Sign-off or adoption

P&S implementation begins with formal sign-off or adoption by the government or the relevant authorities and agencies. Leadership and support at a high level signal the strategy's importance and enhances interested parties' commitment.

### 4.3.2. Assigning resources

Assigning appropriate resources is essential to the success of the strategy. Both monetary resources (to finance economic instruments, communication or education initiatives and new infrastructures) and human resources (to meet the new functions on strategy follow-up and oversight of the regulated activities) need to be provided.

The total cost, including its distribution over time, will already have been estimated in the strategy development phase.

It is critical to sound policy making to ensure an adequate provision of services (e.g. radionuclide measurement capacity or expert advice on diverse aspects, such as residue sampling strategies or radiation protection programmes). A lack of qualified educated personnel with field experience is a common challenge in most countries introducing NORM regulation. In this regard, the county needs to ensure availability of:

— Capacity building activities, including training courses and workshops; e-learning and distance training material or courses; and on-the-job training for national experts and technicians for acquiring skills and knowledge;
— Establishment of 'train the trainer' models and transfer of specialized knowledge from the most experienced countries;
— Accreditation/authorization schemes or alternative mechanisms for the recognition of laboratories or services and the certification of professional competence.

### 4.3.3. Communication

The formal sign-off of the P&S can be used to launch a communication campaign designed to ensure that the target audience includes all the relevant actors identified at the previous phase. All communication needs to ensure technical accuracy and be provided in a timely manner.

Effective channels need to be identified for reaching the different interested parties, disseminating messages and distributing materials. Posters, leaflets and on-line materials can be developed and distributed and the relevant information, including the P&S document, made available on-line.

Coordination with partners can be sought to achieve greater outreach, especially to local communities and, where appropriate, small and medium enterprises, which will face more difficulties in accessing and understanding the information. Communicators need to first build awareness of existing risks and stress benefits, as this will motivate overcoming possible barriers in strategy implementation.

### 4.3.4. Ensuring compliance

A fundamental part of any strategy in which regulation plays a major role is ensuring compliance. The essence of all successful residues management strategies lies primarily in the participants being willing to follow good practices and having the means and capacity to do so consistently. Nevertheless, there need to be effective enforcement mechanisms in place against those who do not comply with regulation in order not to discourage the majority of well behaved regulated companies.

Having enough personnel in the inspectorate, as well as the application of a risk based inspection approach and dissuasive and proportionate sanctions, are important factors of success.

Operators and waste managers, and particularly, small and medium enterprises, might need support to comply with their new duties, as they might face difficulties in getting expert advice or recruiting adequate professional human resources. In some countries, the functions of the inspectorate include supporting the industry through the provision of clear and easily accessible advice. Where that is not the case, it might be necessary to put in place alternative mechanisms to bridge the gap. Special programmes, including provision of support, will also be needed in countries where the informal sector contributes significantly to NORM residues generation or management.

## 4.4. REVIEWING AND UPDATING THE STRATEGY

Any strategy needs to be monitored and reviewed to ensure that it is complied with and that it works as intended in achieving objectives, as well as to allow dynamic adjustments to be made to maximize its effectiveness and avoid losing momentum.

### 4.4.1. Monitoring and reviewing

A steering committee can be created to oversee monitoring, to review the effectiveness of the strategy and to propose the necessary updates. This committee might comprise members of the coordination committee convened during the development phase; however, it might also include additional members who are well suited to evaluate how well the strategy is working. If participation is at a high level and its representatives are empowered to influence the course of the strategy, the advantages of establishing such a committee can be significant.

Monitoring should be conducted based on the KPIs previously defined in the strategy document. Indicators serve to provide data on trends in NORM residues generation in the various regulated sectors. In addition, they will serve to assess trends on recycling and recovery. The data provided by the indicators will also act as a baseline to evaluate the effectiveness of the strategy and of future policy measures that could have an impact on industrial waste management in general.

Strategy review is the process of determining the value of what the strategy has achieved in relation to the intended policy goals and objectives. It involves making value judgements based on the comparison of the results of the KPIs with the predefined targets, whereas monitoring consists of observation and reporting of observations.

For NORM residues management, the review process accounts for strategic issues, such as policy relevance, effectiveness, efficiency and sustainability.

#### 4.4.2. Analysing changes and trends

A forward-looking approach is needed to anticipate future issues and challenges based on the interdependencies with other related policy areas (for example, industrial development, environmental control of industrial discharges or the management of contaminated land). When import and export of NORM residues is allowed, changes regarding NORM residue generation and control measures internationally are also a factor to be taken into account.

An analysis of trends and changes is thus a necessary element of policy review and update, in particular regarding needs for treatment or disposal infrastructures.

#### 4.4.3. Updating the strategy

Where enough change is required, the entire strategy has to be updated. Nevertheless, it is common to undertake periodic updates of the strategy, with a predefined frequency. This frequency does not necessarily need to be the same for P&S updates, in particular, where the national strategy for the life cycle management of NORM residues is developed under the umbrella of the policy on radioactive waste management.

## 5. CONCLUSIONS

The occurrence of NORM is common to various industries that have traditionally accounted for the largest share of industrial waste generation worldwide, such as the extractive sector (e.g. mining, oil and gas production and primary metal production) and the chemical industry (e.g. manufacturing of phosphate fertilizers or titanium dioxide). NORM residues contain not only natural radionuclides but also potentially hazardous chemicals and toxic substances that, when not properly managed, could pose significant risks to human health and to the environment.

While safety remains a core value in NORM residues management, sustainability has emerged as an imperative need, now and in the future, to preserve our planet. A key role in the transition to sustainability is to be played by the circular economy, which implies a shift from a linear 'extract-make-dispose' model of growth to a sustainable alternative that seeks to prevent waste generation and extract value from the already existing or still unavoidable waste.

In the context of NORM management, international efforts and declarations (such as the UN SDGs) need to be underpinned by national policies and strategies, along with a change in regulations on residues and waste. This publication has outlined the main principles and elements for making and adopting national policies on NORM residues management that cope with the current pressing need to find environmentally sound management solutions while pursuing the circular economy paradigm. More detailed considerations of the circular economy aspects of NORM residues will be formulated in a dedicated publication that will cover the topic of valorization of NORM residues in line with the principles of the circular economy.

In this publication, a structured framework has been proposed to support countries in achieving national strategies that can deliver the desired policy goals. This framework consists of several steps within each of the three phases of the strategy cycle: development, implementation, and review and update.

To build trust and achieve groundbreaking outcomes, stakeholder participation is essential throughout the cycle. Accordingly, this publication highlights the roles that information and education play as pivotal factors in policy success. In addition, it underscores the benefits of economic instruments to support private initiatives and foster technological innovation, and it advocates for an evidence based approach — using targets and indicators based on high quality quantitative data — to strategy making.

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# CONTRIBUTORS TO DRAFTING AND REVIEW

| | |
|---|---|
| Bin Ibrahim, M. | Malaysia Nuclear Agency, Malaysia |
| Bradley, D. | University of Surrey, United Kingdom |
| Canobas, A. | Argentina Nuclear Regulatory Authority, Argentina |
| Çetin, B. | Turkish Atomic Energy Authority, Türkiye |
| Diab, H. | Egyptian Nuclear & Radiological Regulatory Authority, Egypt |
| García-Talavera, M. | Nuclear Safety Council, United Kingdom |
| Garcia-Tenorio, R. | Universidad de Sevilla, Spain |
| Gutierrez Villanueva, J. | Grupo Radon, Sweden |
| Jonkers, G. | Consultant, The Kingdom of the Netherlands |
| Kallio, A. | Regional Laboratory of Northern Finland, Radiation & Nuclear Safety Authority, Finland |
| Le Thi Mai, H. | Institute for Radioactive and Rare Elements VINATOM, Viet Nam |
| Leier, M, | Environmental Board of the Republic of Estonia, Estonia |
| Lewis, J. | Chevron, United States of America |
| Marijanski, M. | International Atomic Energy Agency |
| Mohamad El Haji, T. | Universidade Federal de Alfenas, Brazil |
| Monken-Fernandes, H. | International Atomic Energy Agency |
| Murzabekova, A. | Ministry of Emergency Situations of the Kyrgyz Republic, Kyrgyzstan |
| Popic, J. | Norwegian Radiation & Nuclear Authority, Norway |
| Schmidt, P. | Wismut GmbH, Germany |
| Schroeyers, W. | Hasselt University, Belgium |

| | |
|---|---|
| Siwila, B.D. | Radiation Protection Authority Zambia, Zambia |
| Smith, A. | Independent consultant, United Kingdom |
| Smith, K. | Pacific Northwest National Laboratory, United States of America |
| Solente, N. | Andra, France |
| Terziev, V. | Eco Programme Ltd, Bulgaria |
| Tkaczyk, A. | Tartu University, Estonia |
| Valinhas, M. | Petrobras, Brazil |
| Woju, C.W. | Ethiopia Biotechnology Institute, Ethiopia |
| Yoon, J. | Korea Radioactive Waste Agency, Republic of Korea |

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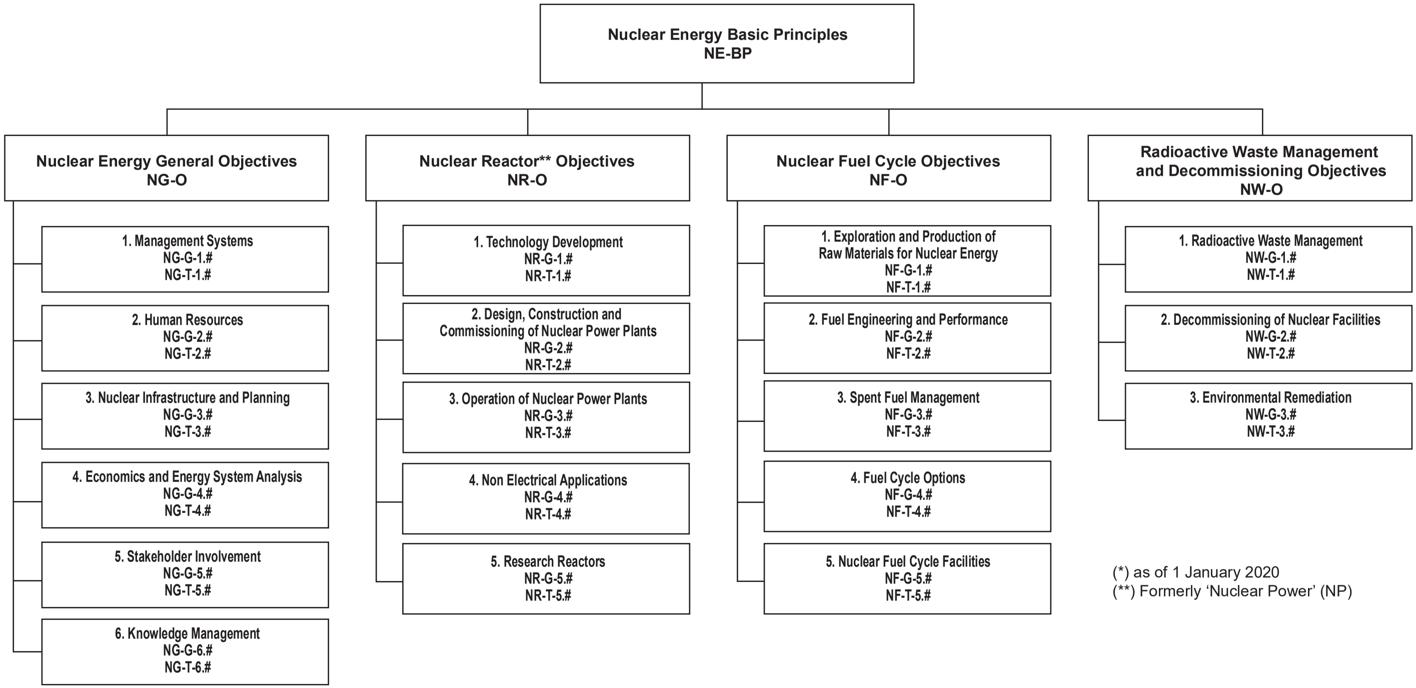


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