DANISH HEALTH
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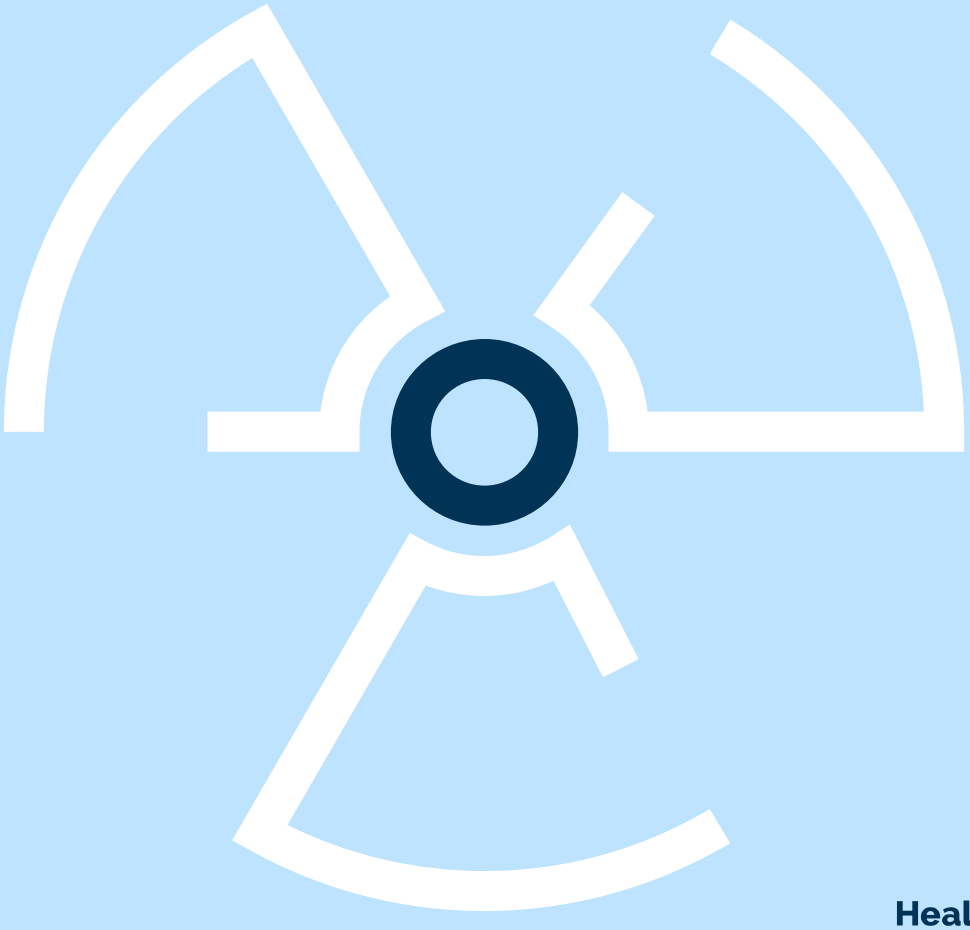
National Programme for the Responsible and Safe Management of Radioactive Waste

Denmark



Health for all

National Programme for the Responsible and Safe Management of Radioactive Waste
Denmark

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Table of contents

Foreword

This document was prepared following the general recommendations for the contents of a lead document for a National Programme as proposed by the European Nuclear Energy Forum in Guidelines for the establishment and notification of National Programmes under the Council Directive 2011/70/EURATOM of 19 July 2011 on the responsible and safe management of spent fuel and radioactive waste. The format has been adapted to the particular national circumstances characteristic for the Danish national programme.

The document provides an overview of the Danish national programme with the objective of serving as a key reference for the public and stakeholders, as well as for the notification of the Commission in accordance with the provisions of the abovementioned directive.

The document was prepared by the Danish Health Authority under the Ministry of Health and by the Danish Agency for Higher Education and Science under the Ministry of Higher Education and Science. The national radioactive waste management organization, Danish Decommissioning, provided information with respect to the national inventory, waste management methods and technical solutions as well as its research, development and demonstration plans and activities.

Summary

The Danish national programme for responsible and safe management of radioactive waste represents the outcome of processes extending almost 20 years back in time. Based on a number of Parliamentary resolutions and agreements as well as surveys and technical studies which were initiated in 2003, the national programme amalgamates the outcome of a stepwise approach toward a comprehensive system for safe management of all types of radioactive waste, in the long term based on passive safety features.

The bulk of the Danish radioactive waste inventory stems from operational and decommissioning activities at the (only) national nuclear facility located at Risø, North of Roskilde, approximately 30 km West of Copenhagen. Decommissioning of the nuclear facilities commenced in 2003, after about 40 years of operation of three research reactors and supporting facilities, including waste management and storage facilities. In the same period, comparatively minor amounts of radioactive waste from institutional users in Denmark was also received and stored at the site. Decommissioning activities are nearing an end, and the combined projected inventory of radioactive waste intended for disposal is currently estimated at 5-10.000 m^3 of LLW and ILW, including a small quantity of experimentally irradiated fragments from spent fuel ("special waste"), accounting for approximately 90 % of the long-lived activity in the waste.

The decision to initiate decommissioning of the nuclear facilities was provided through adoption of Parliamentary Resolution B48/2003, which also provided for the first steps towards development of a disposal solution for radioactive waste in Denmark. This decision was supplemented in 2018 by adoption of Parliamentary Resolution B90/2018, specifying that radioactive waste from operation and decommissioning of the nuclear facilities as well as from institutional use in Denmark is to be stored for up to 50 years prior to disposal in a Danish disposal facility. The resolution provides options for searching for international solutions for the "special waste" and includes provisions for establishing a deep geological disposal facility, should these efforts prove unsuccessful. The parliamentary resolutions define the political framework (the policy), stating principles and long term goals for radioactive management in Denmark, to be implemented through the provisions of the national programme.

The national programme operates in technical and socio-economic areas, engaging stakeholders ranging from the national radioactive waste management organisation (Danish Decommissioning), ministerial agencies, regulatory authorities, municipal and local stakeholders through policy forming fora.

In the technical areas, the programme specifies areas of activity concerning Waste Management, Geology and Siting and development of Disposal Solutions. Activities are organised in such a way as to ensure completion of the decommissioning tasks related to the nuclear facilities and transfer of all radioactive waste into upgraded storage facilities.

The upgraded storage facilities will in turn be the centre for further pre-disposal management, including research, development and demonstration activities over a period of up to 50 years. As part of these activities, the technical, organisational and political options for management of the “special waste” will be integrated with the work to identify a site and develop a disposal solution which is safe and acceptable for stakeholders, and which may include the “special waste” if international options remain untenable.

Research activities at the nuclear facilities at Risø were state-sponsored, and as such there has been no source of tax revenue from waste producers to contribute to cost coverage of the national programme for management of radioactive waste. Consequently, the Danish state covers the financial costs relating to the implementation of the national programme. Funds are secured as reserve fund allocations on the Financial Act adopted annually by Danish Parliament, and has been allocated with reference to Parliamentary Resolution B48/2003 and Parliamentary Resolution B90/2018. On this basis, cost estimations for decommissioning of the nuclear facilities, construction of an upgraded storage facility and an operational period of up to 50 years, followed by development of a disposal solution and subsequent institutional control have been developed.

Implementation of the national programme rests on the legal and regulatory framework established for the safe management of radioactive waste. The framework assigns responsibility for planning, conduct and implementation of the national programme, and prescribes reporting and monitoring mechanisms with the purpose of ensuring the timely implementation of the programme and achievement of the policy goals set out in Parliamentary Resolution B90/2018.

Introduction

Danish legislation defines “radioactive waste” as radioactive material for which no further use is foreseen – and “radioactive material” as a radioactive substance with an activity or activity concentration that cannot be disregarded from a radiation protection point of view.

The largest share of radioactive waste in Denmark originates from the decommissioning of the nuclear facilities at Risø. Radioactive waste also derives from the use of radioactive substances for examinations and treatments in hospitals, industrial applications such as level gauging in tanks, determination of density and humidity in pavements, control of welds and structures as well as for research. Radioactive substances may also occur as a residual product from oil-gas production, burning of coal and production of geothermal heat - sometimes in concentrations requiring the residual to be classified as radioactive waste. In the same way as applies for the use of radioactive material, such radioactive waste must be managed responsibly and such that it does not spread unintentionally or pose a risk to people or the environment.

As a key obligation - under Council Directive 2011/70/EURATOM of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste (hereinafter: Council Directive 2011/70/EURATOM) - Member States shall ensure the establishment, maintenance and implementation of a national programme covering all aspects of spent fuel and radioactive waste management from generation to disposal. The programme must ensure that the objectives of the overarching policy for responsible and safe management of radioactive waste are fulfilled. For a number of Member States, including Denmark, the obligations of the directive for transposition and implementation of provisions related to spent fuel does not apply for as long as it is not decided to develop any activity related to nuclear fuel.

The present document communicates the Danish national programme for the responsible and safe management of radioactive waste. It replaces the national policy and programme previously notified to the Commission[1].

[1] NATIONAL POLICY AND PROGRAM FOR RESPONSIBLE AND SAFE HANDLING OF USED NUCLEAR FUEL AND RADIOACTIVE WASTE IN DENMARK, Communication to the Commission pursuant to Council Directive 2011/70 / EURATOM (2015).

1. Programme background and outline

The Danish national programme for responsible and safe management of radioactive waste rests on a number of Parliamentary resolutions and agreements as well as their consequent measures: surveys and technical studies, which altogether constitute the groundwork for the programme. The Parliamentary decisions, agreements and consequent measures since 2003 are briefly described and depicted below (Figure 1).

By adoption of Parliamentary Resolution B48 on the decommissioning of the nuclear facilities at Risø Research Center (2003) (Parliamentary Resolution B48/2003) it was decided to establish the government owned undertaking, Danish Decommissioning, to decommission the nuclear research facilities at Risø and to solicit a technical study of a radioactive waste disposal solution. Danish Decommissioning commenced activities in 2003, and in 2008 the technical study of disposal solutions, including options for searching for an international solution for a long-lived part of the inventory termed the “special waste” (cf. section 3.1) was presented to the (then) responsible Ministry of Health.

Consequently, in 2009 the Danish Parliament decided to execute the further programming of a waste solution; pre-feasibility studies of disposal concepts were subsequently executed and published in 2011, further local-area studies of six sites with suitable geologies for disposal were published in 2013 and successive environmental assessments of the six possible sites were commenced, but were halted in 2015.

In parallel with the aforementioned pre-feasibility studies, local area studies and environmental assessments, Parliament in 2011 agreed to prepare a decision basis for a long term (up to 100 years) storage facility. A technical study of a long-term storage facility was accordingly published in 2015 and it was decided to carry out further studies on the safety, economy and operation of such a facility. In 2016 the Danish Parliament was presented with a report on the further analyses in order to resume political discussions and decide on options for storage and disposal.

Concurrent with the above activities, Parliament in 2012 decided to investigate the possibility of exporting all Danish radioactive waste - and not just the special waste – abroad. In 2015, after exploring possibilities in 23 OECD countries, it was concluded that export of the total amount of waste was not realistically possible due to legal, technical, and/or political obstacles for such a solution.

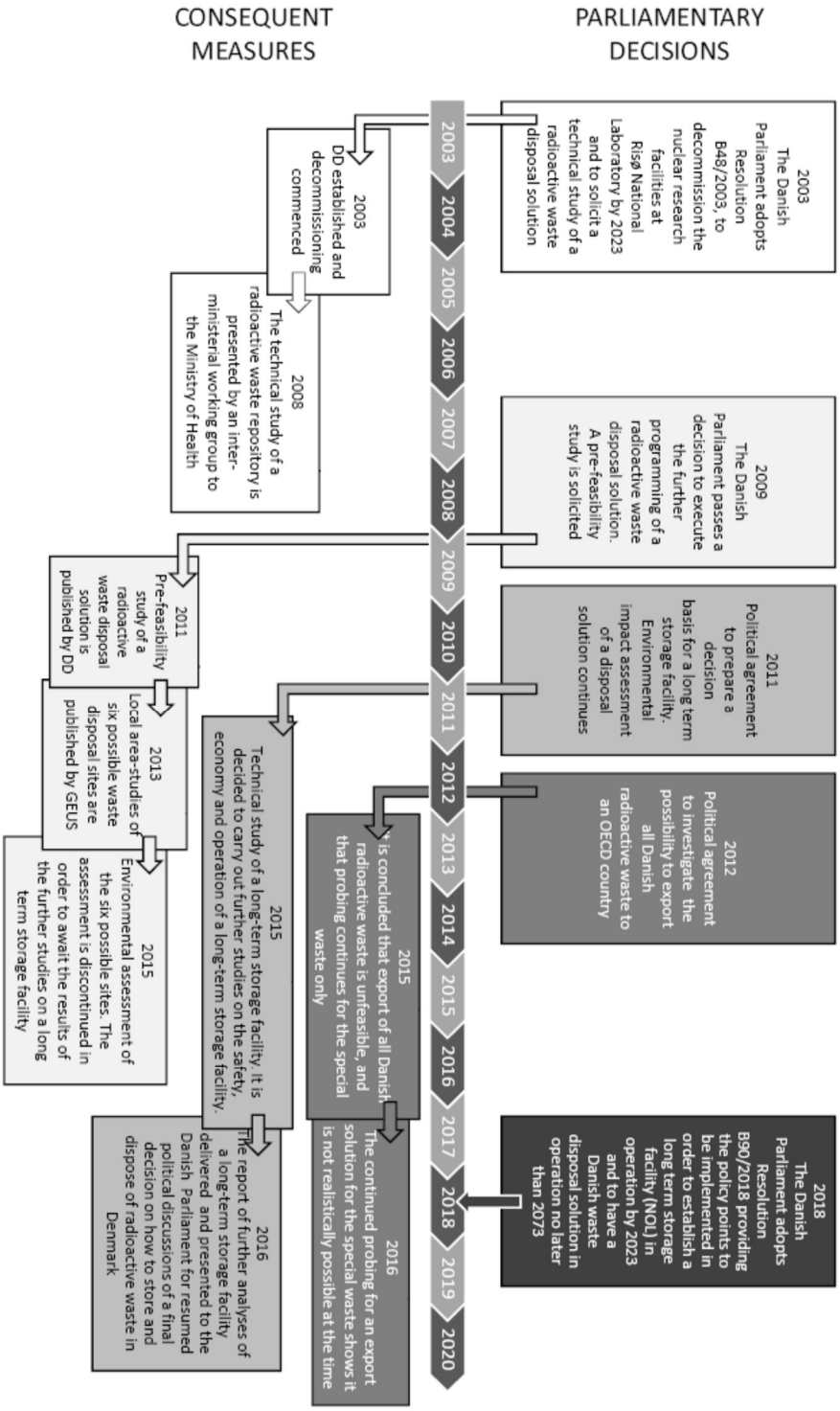

Figure 1: Prior Parliamentary resolutions and resulting inquiries and surveys (Abbreviations: (DD) Danish Decommissioning, (GEUS) Geological Survey of Denmark and Greenland.

By adoption of Parliamentary Resolution B90 on a long-term solution for Denmark's radioactive waste (2018) (Parliamentary Resolution B90/2018), the Danish Parliament provided the policy points to be implemented in order to establish an upgraded storage facility (NOL) for long term storage (up to 50 years) in operation by 2023 and to have a Danish waste disposal solution in operation no later than 2073. Pursuant to the same resolution, the Government will continue to explore possibilities for an international solution for the disposal of special waste, either through export of waste via a bilateral agreement or through participation in an international disposal solution for long-lived radioactive waste.

Parliamentary Resolution B90/2018 holds provisions for including radioactive waste containing naturally occurring radioactive substances (NORM waste) in a disposal solution, but explicitly does not include provisions for the management of NORM waste in the period until a disposal solution is established. Consequently, the Ministry of Health has initiated the setup of a cross-sectoral working group with the participation of relevant authorities, municipalities and with the involvement of NORM industry operators, with the purpose of defining overall policy goals for the safe and responsible management of NORM waste. The resulting policy will rest on the same principles of safety and responsibility as for Parliamentary Resolution B90/2018, and will form the basis for establishing corresponding provisions for management of NORM waste in a national programme context.

1.1. Programme structure

As the implementation and development of a disposal solution will take place over many decades, the national programme reflects the necessity of remaining flexible and adaptable, e.g. in order to incorporate international solutions, new knowledge about site conditions or the possible adaption of the disposal system.

The programme is outlined by the main technical and socio-economic areas considered in Parliamentary Resolution B90/2018 – projected over a timescale from the stipulated completion of the decommissioning of the nuclear facilities (2023) until the latest admissible year of bringing a disposal solution into operation (2073). The timescale is divided into short, mid and long term periods (Figure 2) – which provides the time frame for the course and completion of the main deliveries defined in the programme.

The technical areas are subdivided into "Waste Management", "Geology & Siting" and "Disposal Solution" – whereas the socio-economic areas are subdivided into "Organisational Framework", "Stakeholder Engagement" and "Finance and Costing". The main areas are further divided into a number of variably interdependent deliveries, which take effect in the short term, mid term or long term, or extends over several terms. The remainder of the document refers repeatedly to the main areas, deliveries and terms depicted in Figure 2.

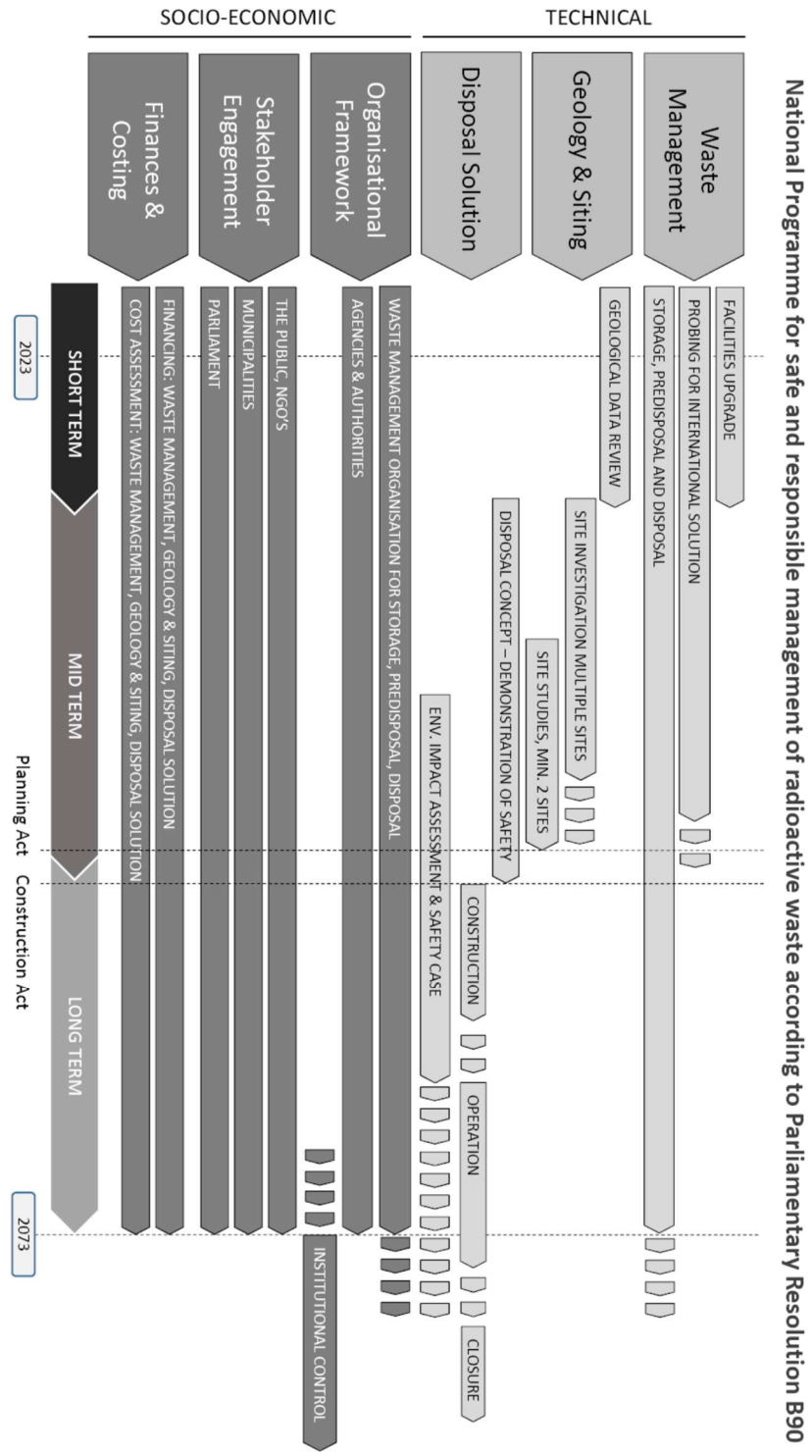

Figure 2, National Programme for the Safe and Responsible Management of Radioactive Waste; Main areas (thick bars), deliveries (thin bars) and terms (bottom bars).

Several processes/deliveries are characterized by open starting/ending points denoting a considerable uncertainty with respect to the exact timing of the given deliveries. On the other hand, defining the commencement of “site investigations, multiple sites” marks the onset of the programme mid-term, whereas the adoption of the Construction Act constitutes the programme's most fundamental key decision defining the onset of the long term, after which the construction of the disposal solution begins.

The technical main areas are characterized by temporary processes leading to deliveries which are prerequisite to the commencement of other technical deliveries – at times delimited by a decision point. On the other hand, the socio-economic action areas are characteristically relevant throughout the entire process and can be characterized as a continuum of repeated tasks, which are typically linked with milestones, deliveries and key decision points defined for some technical areas.

A number of key decisions to a high degree defines the programme and the design of a final disposal solution. Most importantly, Parliamentary Resolution B90/2018 configures the programme, constraining it to a deferred solution for Denmark’s radioactive waste with the objective of long-term storage in upgraded facilities until the localisation and implementation of a geological disposal solution by 2073, at the latest. Subsidiary key deliveries (Figure 2) and key decisions are described below for each of the main areas of the programme.

Waste Management
The waste management area outlines how existing and future radioactive waste is to be characterized, classified, segregated, sorted, minimized and otherwise managed (including long-term storage) in a responsible and safe way before it can be included in a disposal solution.

In the short term, the focus is mainly on the construction of an upgraded storage facility and associated waste management facilities – and transfer of the waste from existing storage facilities to the upgraded storage facility. Short and mid-term storage and predisposal activities mainly involves characterisation and reassessment of the waste inventory in order to identify options for e.g. sorting, segregation, decay storage, volume reduction and reprocessing in a manner that ensures that further waste management as well as implementation of a disposal solution remains possible. Lastly, the outcome of the short to mid term probing for an international solution for the so-called “special waste” is crucial for the final design of the disposal solution. The “special waste” constitutes a limited fraction of the radioactive waste in terms of mass and volume, but accounts for a significant proportion of the long lived activity in the combined inventory, and therefore places critical constraints on predisposal management and disposal options.

Geology and Siting
The Geology and Siting area consists of three successive deliveries which are designed to identify suitable geological site(s), which in combination with a chosen disposal concept provides a safe and acceptable disposal solution for all relevant types of radioactive waste.

The short term delivery is a "geological data review" of available geological data down to a depth of 500 meters, which, together with previously conducted assessments and importantly, possible municipal partnership solutions, will form the basis for the selection of several sites to be subjected to further "site investigations, multiple sites" in the mid term period. On the basis of these studies, two sites will be selected for so-called "site studies", i.e. further geological studies e.g. on the basis of the disposal concepts that appear particularly suitable with respect to the local geological setting and the preceding dialogue with the municipality and local stakeholders. It should be noted in this connection that the particular design of the disposal concept can take into account the possibility of separate solutions – e.g. a deep borehole in combination with a shallow gallery. If the "site studies" show that the combination of geology and concept does not provide a solution which satisfies safety criteria, the "site investigations, multiple sites" will continue in order to identify other geologically suitable sites for further "site studies".

Disposal solution
The disposal solution area outlines the development of one or more "disposal concept(s)", which may be constructed, if the design – in combination with the geological barrier systems - can successfully undergo a demonstration of safety, providing confidence that the combined barrier system of the disposal solution will meet safety requirements. The actually implemented disposal solution will be subject to an EIA assessment. In order to be commissioned and go into operation, the disposal concept must acquire a license on the basis of a safety case, including a supporting safety assessment.

The particular design of the disposal concept must take into account the possibility of separate solutions – e.g. boreholes and galleries – designed for specific types of radioactive waste and that such parts of the disposal facility may subsequently be closed and sealed, completing the disposal process for these waste fractions.

With regard to receiving and disposing of future radioactive waste from users of radioactive material (hospitals, research labs and industry), the disposal facility must include options for receiving radioactive waste to be placed in one or more sections of the disposal facility designed for this purpose, and to be closed and sealed once filled. The planning can take into account a possible need for future extension of the facility with a proposal for acquisition of extra land for a new disposal section.

Organisational Framework
The implementation and development of a disposal solution will take place over many decades, which will require a strong organizational foundation and framework that is

clearly constituted in the legislation and where the individual responsible authorities have clear tasks and mandates from their respective ministries.

Along the entire course of the progamme, the organizational framework must support a parallel development of technical and socio-economic competencies of operators as well as authorities. Only by establishing, maintaining and to some level retaining the necessary level of insight and understanding of all parts of the program - as they develop - can effective progress, an apt process as well as a complete, transparent and straightforward communication with stakeholders – be ensured.

There must therefore be mechanisms that maintain communication and cooperation between the parties involved, as well as mechanisms that ensure that the responsible ministries continuously are informed about the status, progress and barriers to this - and that responsible parties continuously take the necessary position on the state of the program.

Stakeholder engagement
It is Parliament's explicit wish that the overall process is carried out with continuous involvement of all relevant stakeholders in a disposal solution for radioactive waste in Denmark. In addition to the statutory involvement and consultation of the public in different stages of the process, the involvement of stakeholders will include the continuation and adaptation of a contact forum in the case in line with developments, comprising a dialogue forum and communications resource at the final decided location for a disposal facility. Operation of a communications platform with access to all relevant material in the case, and with a contact person function is included in the plan for stakeholder involvement.

Finance and Costing
Financing and cost assessments of all the activities included in the entire programme e.g. waste management, geological investigations, disposal concept development, construction, operation and closure etc. are included in the basis for adoption of Parliamentary Resolution B90/2018. The basis includes general cost analyzes, cost profiles and financing considerations for the proposed long-term solution. The costs are however subject to significant uncertainty, as there is no national experience with locating, designing and constructing facilities of this nature. In addition, the time scale means that the cost profiles may change considerably, pending e.g. the design of the final disposal concept.

Although it by parliamentary resolution is decided to cover the costs of the programme as a whole, there will be a need to partition funding according to the shorter-term budgeting of projects and sub-projects individually - since these can depend on variables such as e.g. geological setting, design concept, export opportunities and the development of new waste management methods. Therefore, as depicted in Figure 2, ongoing cost analyzes and financing for relevant technical and socio-economic deliveries must be carried out over the lifetime of the programme.

2. Policy, Principles & Framework

2.1. National Policy

Through the adoption of Parliamentary Resolution B48/2003 and Parliamentary Resolution B90/2018, the Government established a national policy with initial provisions for the safe decommissioning of the nuclear facilities at the Risø site and the safe management and disposal of the resulting radioactive waste as well as radioactive waste from institutional use of radioactive material in Denmark.

Parliamentary Resolution B48/2003 forms the basis for the current policy on decommissioning and management of radioactive waste. Herein, the Danish Parliament announces its agreement that the Government will promote the decommissioning of the nuclear facilities at Risø Research Center under the independent (state owned) undertaking Danish Decommissioning (DD), in order to release the areas on the site for unrestricted use within a timeframe of up to 20 years. Pursuant to the resolution, the Danish Parliament also gave its consent that the government, at the time of the dismantling (decommissioning), starts preparing a basis for decision for a Danish final disposal facility for low- and medium-level waste.

Parliamentary Resolution B90/2018 further specifies the end goals for management and disposal of these waste streams, and defines the responsibilities of Danish Decommissioning as national waste management organization in the framework of B90. The resolution aims to implement a long-term solution for Denmark's radioactive waste with a view to continued safe storage until the waste may be disposed of in a disposal facility. Parliamentary Resolution B90/2018 enables the short-term improvement to the existing storage facilities at the Risø Peninsula through the construction of a new upgraded storage facility. The resolution facilitates - in the medium term - geological studies at depths of up to 500 meters in order to identify suitable geologies for a deep geological disposal facility in Denmark. After this, a location of the disposal facility can be recommended based on a number of analyzes of geological, physical and socio-economic conditions, in particular the option for voluntary participation by local municipalities/communities. In the long term, Parliamentary Resolution B90/2018 will enable the establishment of a geological disposal facility to be commissioned by 2073 at the latest.

Parliamentary Resolution B90/2018 also allows for the – in parallel – continued exploration of the possibilities for an international solution for the so-called “special waste”, comprising the bulk of long lived activity in the Danish inventory of radioactive waste (cf. section 1.7). The “special waste” will, at the latest at the point in time where a planning act for a geological disposal facility is passed, be included in the inventory to be disposed of in Denmark, should an international solution not have been found for this waste.

Finally, according to Parliamentary Resolution B90/2018, a disposal solution could also be considered for naturally occurring radioactive material (NORM) waste, which is currently stored by the waste owners until a disposal option is decided upon.

2.2. Main Principles

The national policy, as expressed by the abovementioned parliamentary resolutions, must be implemented observing the fundamental principles for radiation protection and safety as well as a number of specific waste management principles in addition.

The fundamental safety principles[2] are directly aimed at protecting people and the environment from the dangers arising from ionising radiation. They are embedded in the Radiation Protection Act[3] and imply that exposure to radiation must be justified, as low as reasonably achievable (ALARA) and below specified limits – while placing primary responsibility by anyone utilizing ionising radiation. According to the Radiation Protection Act, the fundamental safety principles apply to any use of radiation or radioactive sources, - including the management of radioactive waste.

The specific waste management principles as expressed by Council Directive 2011/70/EURATOM entail common standards with respect to; ultimate responsibility, graded approach, waste management phase interdependencies, waste minimization, financial compensation, future generations and transparency. Within the scope of the national programme, the significance of the principles is elaborated below.

2.2.1. Ultimate Responsibility

Denmark takes ultimate responsibility for management of the radioactive waste generated in the country. If radioactive waste is shipped for processing or reprocessing to a different state, the responsibility for the safe and responsible disposal, including any waste as a by-product, ultimately remains with Denmark.

2.2.2. Graded approach

The implementation of waste management measures applies a graded approach to ensure that the necessary level of analysis, documentation and actions are carried out in relation to the magnitudes of any radiological and non-radiological hazards, depending on the nature and specific characteristics of the cause for the measure. This means: the greater the risk, the stricter the regime.

[2] A full account of the fundamental safety principles can be found in IAEA, “Safety Fundamentals”, No. SF-1 (2006).
[3] The fundamental safety principles: 1 (Responsibility), 3 (Leadership and Management for Safety), 4 (Justification), 5 (Optimization), 6 (Dose limitation), 8 (Accident Prevention), 9 (Emergency Preparedness) and 10 (Protective actions to reduce existing or unregulated radiation risks) are articulated directly in the Radiation Protection Act, § 1, § 2, § 4, § 5, § 6, § 7 and § 14.

2.2.3. Interdependencies

The different steps in spent fuel and radioactive waste management are closely interrelated. Decisions taken in one individual step may affect a subsequent step. Therefore such interdependencies must be taken into account in the national programme.

2.2.4. Waste minimization

The generation of radioactive waste shall be kept to the minimum, which is reasonably practicable, both in terms of activity and volume, by means of appropriate design measures and of operating and decommissioning practices, including the recycling and reuse of materials. To the extent possible waste minimization is achieved by preventing the use of radioactive materials (justification), minimizing the activity used (optimization), re-using radioactive sources, avoiding unintended production or import and returning radioactive sources to the producer. Once generated, radioactive waste may be volume-reduced by incineration, distillation or compaction as well as by decay for waste fractions with short-lived radionuclides.

2.2.5. Safe management

Radioactive waste shall be safely managed, including in the long term with passive safety features, for as long as it represents a risk to man and the environment.

There is a notable difference in the approach to safety taken for a geological disposal facility compared with that for a nuclear installation. This is primarily because the core mission of a nuclear installation is carried out during its operating life and thus rely on operational limits and conditions for its active safety systems. In contrast, the core mission of a geological disposal facility for long lived waste is to provide passive safety over time periods of the order of thousands of years and longer. Geological disposal facilities are designed to be passively safe and, following closure, should not rely on intervention, surveillance or control for the assurance of safety. During the operational period, passive features such as shielding and containment provided by the packaging material can provide safety. Safety after closure is provided by passive systems such as geological and engineered barriers, including the facility structure, the containers and the filler material. Geological disposal, at appropriate depths, provides isolation as an inherent safety feature.

2.2.6. Financial compensation

The costs for the management of radioactive waste shall be borne by those who generate the radioactive waste. The "polluter pays" principle is the guiding principle throughout the national environmental policy - for instance set out in The Danish Soil Pollution Act (Consolidation Act no. 282 of 27 March 2017 on Soil Pollution) - aiming to prevent, eliminate or reduce contamination of the soil and to avoid or prevent the harmful effects on groundwater, human health and the environment in general.

2.2.7. Future generations

The health effects on future generations as a result of the long-term solution must not exceed current acceptable levels. The long-term solution must provide the greatest possible safeguard against unintentional ingress on the basis of risk assessments from all relevant

authorities. The long-term solution, no matter its form, and with reference to Council Directive 2011/70/EURATOM, must show consideration for an overall suitable utilization of resources over time, where the economic burden must be borne by the current generation to avoid any unreasonable burden on future generations.

2.2.8. Transparency

The long-term solution must allow for an implementation process that, to the greatest possible extent, involves and creates dialogue with central stakeholders during the localisation, establishing, and operation of a disposal solution.

2.3. Legal and Regulatory Framework

This section provides background information on Denmark's legal and regulatory framework for radiation protection and safety in association with the management of radioactive waste. The legal and regulatory framework constitutes the infrastructure that implements the policy and the programme. It is defined by the regulations, roles and responsibilities assigned to waste producers, regulatory authorities and national operators managing the radioactive waste.

2.3.1. EU and EURATOM

The European Union (EU) and the European Atomic Energy Community (EURATOM) are based on treaties, establishing policy goals and institutions with the necessary legal powers to enact legislation such as regulations and directives. Two directives under the EURATOM treaty to a high degree shape the Danish legislation related to radiation protection and safety as well as to management of radioactive waste.

Council Directive 2013/59/EURATOM of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation – aims to protect people and the environment. This directive lay down fundamental principles and provisions for radiation protection and safety based on standards and recommendations by the ICRP and the IAEA.

Council Directive 2011/70/EURATOM of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste – aims to establish a failsafe system to handle radioactive waste. This directive stipulate specific principles and provisions including for a national policy, a programme and a legal and regulatory framework for the responsible management of radioactive waste.

2.3.2. National Legal Framework

The national legal framework for both radiation protection and safety as well as for responsible and safe management of radioactive waste in Denmark essentially rests on

The Radiation Protection Act[4] and The Nuclear Installations Act[5] and their underlying orders and circulars (an account of the legislative hierarchy can be found in Appendix 1).

The Radiation Protection Act is the main instrument for transposition of Council Directive 2013/59/EURATOM (The European Basic Safety Standards). In addition to the provisions of the Directive, the act implements the framework and principles of The 2007 Recommendations of the International Commission on Radiological Protection, ICRP Publication 103. In covering the ICRP "exposure situations" and "exposure categories", the act is all-inclusive in terms of facilities and activities, applying also to all management of radioactive waste. The act empowers the Danish Health Authority with all regulatory core functions such as authorization, review and assessment, inspection and enforcement.

The Nuclear Installations Act defines the concept of nuclear installations and establishes the fundamental principles for authorization – safety during commissioning, operation and decommissioning of the facilities. It stipulates that the Danish Health Authority under the Ministry of Health and (by later amendments) the Danish Emergency Management Agency under the Ministry of Defence, constitute the Nuclear Regulatory Authorities. The Nuclear Regulatory Authorities are authorized to establish limits and conditions for operation and decommissioning, to issue terms necessary to ensure compliance and to access nuclear facilities at any time. The nuclear installations at Risø, including the national storage facilities for radioactive waste, are subject to oversight and inspection by the Nuclear Regulatory Authorities.

The nuclear facilities at Risø are thus subject to regulatory control by the Danish Health Authority and by the Nuclear Regulatory Authorities at the same time. For the new, upgraded storage facility to be established according to the provisions of Parliamentary Resolution B90, this will also apply, albeit the application of the Nuclear Installations Act will reflect that the upgraded storage facility itself as well as the activities undertaken there, shares few similarities with nuclear installations as such.

The national legal framework comprise additional legislation supporting more distinct aspects of responsible and safe management of radioactive waste, including: The Environmental Impact Assessment Act[6], The Nuclear Safety Act[7], The Health Act[8] , The Public Information Act and The Planning Act - and relevant underlying orders.

Circular no. 9654, 2020 on the tasks of the Danish Health Authority and the Danish Agency for Higher Education and Research concerning responsible and safe management of radioactive waste – provides an important hub in the framework. By this Circular, the Ministry of Health and the Ministry of Higher Education and Science in detail delegate

[4] Act no. 23 of 15 January 2018, on Ionising Radiation and Radiation Protection (The Radiation Protection Act)
[5] Act no. 170 of 16 May 1962, on Nuclear Installations (The Nuclear Installations Act)
[6] Consolidation Act no. 1225 of 25 October 2018 on Environmental Impact Assessment of Plans and Programs and of Specific Projects (EIA)
[7] Act no. 244 of 12 May 1976 on Safety and Environmental Conditions at Nuclear Facilities, etc. (Only § 11 and § 12 (1) is in force)
[8] Consolidation Act no. 903 of 26 August 2019 on Health (The Health Act)

responsibilities and tasks in relation to the fulfilment of the requirements in Council Directive 2011/70/EURATOM, to the Danish Health Authority and the Danish Agency for Higher Education and Research - including the establishment of a national programme.

2.3.3. Regulatory Framework for Safe Management of Radioactive Waste

The regulatory framework for the management of radioactive waste comprise four ministries in the main. Pursuant to the all-encompassing nature of The Radiation Protection Act, the Ministry of Health is responsible for the legal framework in relation to virtually all facilities and activities involving radiation sources including radioactive waste. The Ministry of Health and the Ministry of Defence are responsible for the legal framework governing the administration of the Nuclear Regulatory Authorities. The Ministry of Higher Education and Science is administratively responsible (as operating entity) for the nuclear facilities in Denmark, which are all government property.

The Danish Health Authority

The Danish Health Authority acts under the Ministry of Health. The main tasks include health promotion, disease treatment and prevention – the latter including radiation protection and safety. In accordance with The Radiation Protection Act, the Danish Health Authority is the national competent authority for regulating the use of radioactive substances including radioactive waste. The everyday administration of the obligations and powers of the act is delegated to the Danish Health Authority, Radiation Protection. Pursuant to the Nuclear Installations Act, the Danish Health Authority and the Danish Emergency Management Agency constitute the Nuclear Regulatory Authorities – and as such conduct inspections of nuclear installations, including storage facilities (see also section 2.3.2). The Danish Health Authority has been assigned particular responsibilities in relation to the implementation of the programme. The relevant legislation is:

1. The Radiation Protection Act (Act no. 23 of 15 January 2018 on Ionising Radiation and Radiation Protection) and the following underlying Executive Orders transpose the large majority of the EU-BSS provisions into Danish legislation:
    1.1. Executive Order no. 669 of 1 July 2019 on Ionising Radiation and Radiation Protection.
    1.2. Executive Order no. 670 of 1 July 2019 on Use of Radioactive Substances.
    1.3. Executive Order no. 672 of 1 July 2019 on Transboundary Shipments of Radioactive Waste and Spent Nuclear Fuel.
    1.4. Circular no. 9654, 2020 on the tasks of the Danish Health Authority and the Danish Agency for Higher Education and Research concerning responsible and safe management of radioactive waste
2. The Nuclear Installations Act (Act no. 170 of 16 May 1962 on Nuclear Installations)
    2.1. Circular no. 9450 of 9.July 2020 on the regulatory control exercised by the nuclear regulatory authorities regarding the nuclear safety of nuclear installations, etc.

The Danish Agency for Higher Education and Science

The Agency for Higher Education and Science has the formal responsibility for institutions under the Ministry of Higher Education and Science, including Danish Decommissioning (DD). The primary tasks of DD are to: 1) Dismantle the nuclear research facilities

at Risø by 2023, in a safe, environmentally sound and economically optimal way, 2) receive, process and store radioactive waste from Danish users of radioactive material and 3) participate in the process that lead to a long-term solution for the radioactive waste by 2073 - until then, storing the waste. The Danish Agency for Higher Education and Science has been assigned particular responsibilities in relation the implementation of the national programme. The relevant legislation is:

1. Parliamentary Resolution B48, 2003 on the Decommissioning of the Nuclear Facilities at Research Station, Risø.
2. Parliamentary Resolution B90, 2018 on a Long-Term Solution for Denmark's Radioactive Waste.
3. Executive Order no. 1229 of 3 November 2015 on Resort Changes between Ministers
4. Circular no. 9654, 2020 on the tasks of the Danish Health Authority and the Danish Agency for Higher Education and Research concerning responsible and safe management of radioactive waste.
5. Circular no. 64, 2012 on Danish Decommissioning.

The Danish Emergency Management Agency

The Danish Emergency Management Agency (DEMA) is responsible for Danish emergency preparedness and acts under the Ministry of Defense. DEMA supervises authorities and municipalities on emergency preparedness and comprise the second half of the Nuclear Regulatory Authorities. Pursuant to the Nuclear Installations Act, the Danish Emergency Management Agency and the Danish Health Authority constitute the Nuclear Regulatory Authorities.The relevant legislation is:

1. The Nuclear Installations Act (Act no. 170 of 16 May 1962 on Nuclear Installations)
    1.1. Circular no. 9450 of 9.July 2020 on the regulatory control exercised by the nuclear regulatory authorities regarding the nuclear safety of nuclear installations, etc.
2. The Emergency Management Act, Nuclear Preparedness Chapter 7a (Consolidation Act no. 314 of 3 April 2017 on Emergency Management).
    2.1. Executive Order no. 1762 of 27 December 2016 on Security Measures for Nuclear Material and Nuclear Facilities and Drafting of Security Plans.
3. The Nuclear Safety Act (Act no. 244 of 12 May 1976 on Safety and Environmental Conditions at Nuclear Facilities, etc.) (Only § 11 and § 12 (1) is in force).
    3.1. Executive Order no. 278 of 27 June 1963 on Protective Measures against Accidents at Nuclear Facilities, etc. – as changed according to Executive Order no. 502 of 10 January 1974.

The Danish Environmental Protection Agency

The Danish Environmental Protection Agency is part of the Ministry of the Environment and Food, and it administers the legislation on environmental protection, which is to ensure clean air, (drinking-) water and soil and good living conditions for people, animals and nature. The Environmental Impact Assessment Act as well as the Planning Act (under the Ministry of Business) are relevant in the planning and siting of facilities such as nuclear facilities or a disposal facility for radioactive waste. The relevant legislation is:

1. The Environmental Impact Assessment Act (Consolidation Act no. 1225 of 25 October 2018 on Environmental Impact Assessment of Plans and Programs and of Specific Projects (EIA).
2. The Environmental Protection Act (Consolidation Act no. 1218 of 25 November 2019 on Environmental Protection)

The Danish Business Authority (Ministry of Business)
The Danish Business Authority administers The Planning Act on involving the public in a coherent planning that combines social interests in land use, contributes to protect nature and environment, and creates a good framework for growth and development throughout the country. The Planning Act as well as the Environmental Impact Assessment Act are relevant in the planning and siting of facilities such as nuclear facilities or a disposal facility for radioactive waste. The relevant legislation is:

1. The Planning Act (Consolidation Act no. 287 of 16 April 2018 on Planning).

2.4. Transparency Policy and Public Involvement Processes

Transparency and access to information is regulated by the following acts in Danish legislation:

- *Public Access to Information Act (Statutory Order No. 145 of 24 February 2020)*
- *Public Access to Environmental Information Act (Statutory Order No. 980 of 16 August 2017)*.

The Public Access to Environmental Information Act transposes *Directive 2003/4/EC of the European Parliament and of the Council of 28 January 2003 on public access to environmental information and repealing Council Directive 90/313/EEC* into Danish legislation.

The Public Access to Environmental Information Act gives the public right to access official documents, provided the documents are not subject to secrecy. Civil and local government servants are also entitled to disclose information to a third party under the condition that information is not subjected to confidentiality.

Public participation in issues pertaining to radioactive waste management is enshrined in Danish environmental legislation by the *Environmental Assessment of Plans, Programmes and Projects Act (EIA) (Statutory Order No. 973 of 25 June 2020)*. This act transposes *Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment* and subsequent EU legislation into Danish legislation.

Citizens have the right to submit responses in public consultations on environmental assessment of plans, programmes and projects. Consultations are published on the website of the Danish Environmental Protection Agency[9]. A subscription service to notifications of consultation is made available to the general public at the website[10].

[9] (https://mst.dk/natur-vand/miljoevurdering/ (in Danish only))
[10] (https://mst.dk/service/annoncering/miljoevurderinger/ (in Danish only))

Public participation in decision making with regard to national policy on radioactive waste management is addressed in Parliamentary Resolution B48/2003 (Section 17.1), Parliamentary Statement R4/2009, and Parliamentary Resolution B90/2018 (Section VIII). Public participation is supported by the following initiatives:

- Information dissemination on dedicated websites
- Public hearings
- Facilitation of stakeholder dialogue through contact fora (cf. 2.4.2), e.g. the national contact forum consisting of representatives of NGOs, Local Government Denmark, Danish Regions and other relevant participants, including public agencies with tasks in either regulation of radioactive waste management or policy development.

2.4.1. Website Hosting and Support

The Ministry of Higher Education and Science is responsible for providing information on Danish policy regarding disposal of radioactive waste and related matters. The Ministry's website contains a dedicated landing page for radioactive waste management posting documents related to political decision processes since 2003, including background information[11]. Access to translations of key documents in English is available at a dedicated landing page[12].

The Danish Decommissioning website[13] provides detailed information on its tasks in relation to decommissioning, waste management and the process towards a long term solution for radioactive waste management in Denmark. An exhaustive list of reports including: Annual health and safety statements, environmental reports and impact statements, decommissioning plans/strategies/reports, lessons learned reports can be found at the website[14].

The Danish Health Authority website provides information on the authority's role as an impartial organization deciding whether safety and radiation protection are adequate in any context where handling, storage and disposal of radioactive waste takes place. It furthermore provides links to relevant organizations as well as reports to international bodies on compliance with directives and conventions on responsible and safe handling of radioactive waste[15].

2.4.2. Contact Fora

The Ministry of Higher Education and Science hosts the contact forum instrument. So far, two contact fora have been established:

- A National Contact Forum (established in 2016) which is a forum for discussion of issues relating to national policy on radioactive waste management, including the long-term solution of Parliamentary Resolution B90/2018.

[11] (https://ufm.dk/aktuelt/temaer/deponering-af-radioaktivt-affald-i-dk (in Danish only))
[12] (https://ufm.dk/en/newsroom/issues/radio-active-waste?set_language=en&cl=en)
[13] (https://dekom.dk/en/)
[14] (https://dekom.dk/en/publikationer/?frm-page-3914=1)
[15] https://www.sst.dk/da/Opgaver/Straalebeskyttelse/Tilsyn-og-lovgivning/Radioaktivitet/Radioaktivt-affald

- A local contact forum, Contact Forum Roskilde (established in 2018), which is a forum dedicated to stakeholders in Roskilde Municipality. Contact Forum Roskilde specifically discusses issues relating to the project of upgrading Danish Decommissioning's storage facilities on the Risø peninsula.

The contact forum instrument is not restricted to the two examples above, but may be expanded to cover other local communities or specific issues in the further execution of the long-term solution for radioactive waste management, i.e. in connection with the siting process of a disposal facility, as per demand.

2.4.3. The Panel of Independent Experts

In recognition of a demand from NGOs and concerned citizens' groups for access to independent, scientifically vetted second opinions on issues of radioactive waste management, the Ministry of Higher Education and Science hosts a Panel of Independent Experts, consisting of seven university-based scientists within the following fields:

- Nuclear Physics/Nuclear Energy
- Radioactive Waste Management
- Health Physics/Radiation Protection
- Environment Assessment
- Environmental Law
- Public Governance
- General Ethics.

Members of the panel are appointed by scientific peers of the five councils of Independent Research Fund Denmark[16]. Appointments take place in observation of the arm's length principle. The Ministry of Higher Education and Science offers administrative service to the panel and facilitates communication between public and panel.

The Panel of Independent Experts responds to questions from the public as per demand. Questions and answers are posted on the website of the Ministry of Higher Education and Science.

2.5. Agreements with other Countries or Contractors Abroad

Spent fuel from the operational period of the research reactors was returned to the USA in 2002, In accordance with an agreement between authorities in Denmark and USA.

At present, no agreements on management of spent fuel or radioactive waste, including the use of disposal facilities, have been concluded between Denmark and other Member States or third countries.

[16] (https://dff.dk/en/about-us)

Parliamentary Resolution B90/2018 includes a provision (Section IX) that the Danish Government continues to explore potential options of entering an intergovernmental agreement on the use of disposal facilities for the “special waste” in the Danish waste inventory. The exploration process is conducted by the Ministry of Foreign Affairs.

In the event that no intergovernmental agreement can be concluded, the provision is set to expire by the time of decision making on a Danish disposal facility project. The “special waste” will continue to be included in the project planning of a disposal facility in Denmark.

The Danish legislation enables the use of contractors abroad for conditioning Danish radioactive waste, for example in order to reduce waste volume in accordance with the specific waste management principles (section 1.2). Well-sorted and combustible waste can, with the authority's permission, be temporarily transferred to a contractor in another country for the purpose of e.g. incineration, whereby a significant reduction in waste volume is achieved. Likewise for volume reduction of metallic waste fractions suited for treatment in melting facilities abroad. The radioactive substances remain, but the radioactive material takes up significantly less space when it is returned to Denmark for storage and final disposal.

3. Waste Inventory

The general requirement for characterisation of radioactive materials, including radioactive waste, is set in Executive Order no. 670 of 1 July 2019 on Use of Radioactive Substances. Chapter 4 in the Executive Order sets provisions for registration and recording of reception, production and transfer of radioactive materials. For each container, the records must reflect nuclide contents of the radioactive material, the chemical and physical form of the radioactive material, dates of reception, storage etc., storage location as well as name(s) of responsible contact person.

Circular no 9654 of 18. September 2020 on the tasks of the Danish Health Authority and of the Danish Agency for Higher Education and Science pertaining to responsible and safe management of radioactive waste stipulates in § 4. 3) that the Danish Health Authority, as part of the duties related to the implementation and maintenance of the national framework for radioactive waste, and with contributions from responsible license holders, shall assist the Ministry of Health in quantifying and continuously updating the national inventory of radioactive waste, including expected future waste. In this effort reference to international standards of classification and quantification of radioactive waste shall be given.

3.1. Waste Classification

In accordance with these provisions, the Operational Limits and Conditions for Danish Decommissioning specify that waste classification should be based on IAEA's General Safety Guide GSG-1 Classification of Radioactive Waste (2009). Furthermore, it is stipulated, that the use of the waste category "Very Low Level Waste" (VLLW) may only be used following approval.

Further to the provisions, the Danish Health Authority is registered as the national point of contact for Denmark with the IAEA´s Spent Fuel and Radioactive Waste Information System, with the purpose of facilitating the recasting of a combined and updated Danish inventory into a versatile format for extracting information in support of decisions and for presenting inventory information of relevance for the national programme.

Efforts pursuant of the adoption of Parliamentary Resolution B48/2003
The initial steps to characterize and classify the Danish national inventory of radioactive waste were initiated subsequent to the adoption of Parliamentary Resolution B48/2003 concerning the decommissioning of the nuclear facilities at the Risø Research Facility site. In the resolution, the Danish Parliament granted approval for the Danish Government to commence, concurrently with the decommissioning programme, the preparation

of decision-support materials[17] for a Danish disposal facility for low- and intermediate-level waste.

Following adoption of the resolution, Danish Decommissioning initiated a series of preliminary studies targeted at providing a basis for a political decision on the long term plans for management of the radioactive waste stored at the Risø site and resulting from the decommissioning activities. The preliminary studies addressed disposal concepts regional geological studies and transport of radioactive waste. For an overview of the findings in these studies (in Danish) kindly refer to the Ministry of Higher Education and Science website[18].

In the Pre-feasibility study for final disposal of radioactive waste (2011)[19] the combined knowledge of the known radioactive waste inventory and anticipated future waste[20], formed the basis for examining which conceptual solutions for disposal could be considered feasible to implement in a typical Danish geological setting. The waste types considered in the study included waste originating from the nuclear research previously carried out at Risø, as well as Danish institutional users of radioactive materials (e.g. the health sector, research institutions and the industry). Based on radiological as well as other physical and chemical characteristics the combined inventory of waste was grouped into 20+ groups. The options for disposal of waste in each group was evaluated taking into account the requirements for isolation of the waste from the biosphere as specified in the Commission Recommendation of September 15, 1999 as well as the IAEA General Safety Guide (GSG-1) (2009).

Following these evaluations, it was concluded that the combined inventory of radioactive waste may be classified as low level waste (LLW) and intermediate level waste (ILW) according to the provisions of IAEA General Safety Guide (GSG-1) (2009). The overall types and amounts of radioactive waste classified as LLW and ILW, the latter with a subgroup of waste termed “special waste” primarily consisting of fragments of experimentally irradiated spent fuel with moderate activity concentrations and negligible heat generation.

The overview of the inventory of radioactive waste is presented in national reports from Denmark for the Joint convention on the safety of spent fuel management and on the safety of radioactive waste management, in reporting following the provisions of Council Directive 2011/70/EURATOM, and in section 1.7.1 below.

Efforts pursuant of the adoption of Parliamentary resolution B90/2018
With the adoption of Parliamentary resolution B90 (2018), the objectives regarding disposal of radioactive waste stored at the Risø site and resulting from the decommissioning activities were re-scoped with the inclusion of the option for disposal in a deep geological disposal facility at depths down to 500 m below the surface.

[17] Can be found at: https://ufm.dk/aktuelt/temaer/deponering-af-radioaktivt-affald-i-dk/slutdepotlosning
[18] https://www.dekom.dk/wp-content/uploads/publikationer/langsigtet-loesning/2011_slutdepot_forstudier_hovedkonklusioner_anbefalinger.pdf
[19] https://inis.iaea.org/collection/NCLCollectionStore/_Public/42/086/42086372.pdf
[20] (also referred to as “arisings”)

Despite the finding in the Pre-feasibility study for final disposal of radioactive waste (2011), that the total amount of radioactive waste could safely be disposed of in a medium depth disposal facility, as indicated by the classification as LLW and ILW, the consideration of a deep geological disposal facility was included in Parliamentary Resolution B90/2018 to meet public criticism that this was not included in the preliminary studies.

Furthermore, the decision to store the radioactive waste for up to 50 years, until a disposal solution is operational by 2073 at the latest, opens the field for exploring management options with a view to minimize the volume and amount of activity of the waste to be disposed of through volume reduction and decay.

The general options for management of radioactive waste in the framework of Parliamentary Resolution B90, cf. Chapter 1.1, is presented in figure 3 below:

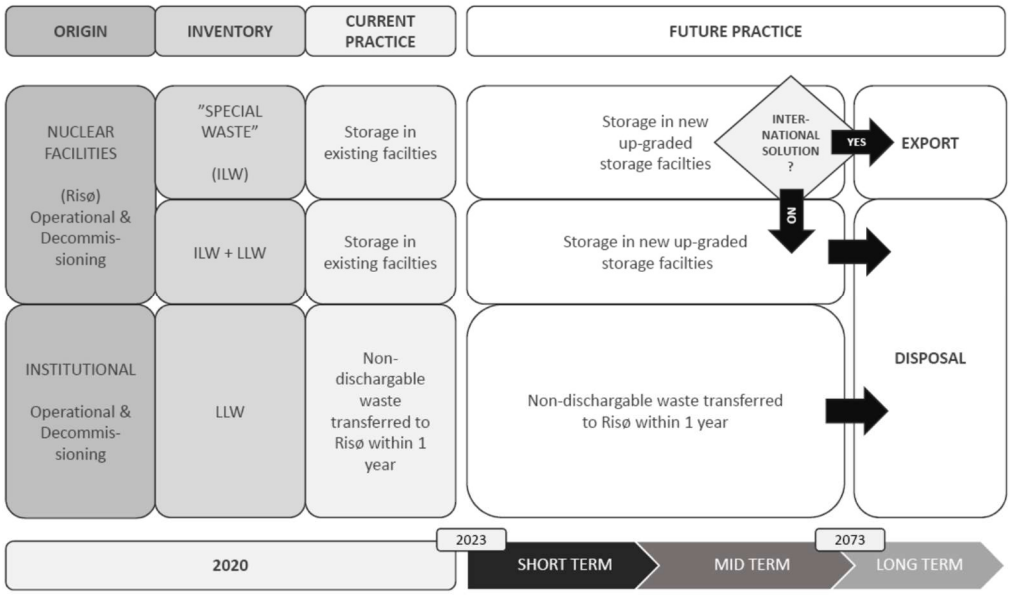

Figure 3, Origin and Classification of radioactive waste indicating Current and Future Practice. The decision point “International Solution” denotes the point in time where the upcoming Parliamentary adoption of the Planning Act excludes further searching for an international (export-) solution for the “special waste”.

The figure outlines the origin of radioactive waste, the classification and the current practice for management of these waste streams, and illustrates the options and decision-points for management within individual waste streams, pursuant of Parliamentary Resolution B90. In the storage period until disposal, several activities related to predisposal management are envisaged, and further described in Chapters 4 and 5, and underpinned by a re-assessment of the inventory of radioactive waste foreseen to be generated, stored, managed in the period until a disposal solution is to be operational by 2073 at the latest.

Re-assessment of inventory of radioactive waste
As a result, the previous assessments of the radioactive waste inventory must be re-addressed to reevaluate options for disposal as well as requirements and options for management of the radioactive waste over a timeline running up to 50 years into the future.

The re-assessment will address these perspective for each of the waste groups identified in the pre-feasibility study for final disposal of radioactive waste from 2011, verifying the validity of the grouping or providing updates to it, and outlining how the information provided in this updated inventory is to be used in support of decisions regarding radioactive waste management, taking into account the endpoints defined in Parliamentary Resolution B90 and the interdependencies between different stages in waste management.

Based on these considerations, the following framework for re-assessment concerning LLW and ILW, including the special waste, has been established:

LLW
- The perspectives of decay storage with a view to release from regulatory control before 2073, to be evaluated for each relevant group of LLW.
- Options and feasibility of carrying out segregation and/or further volume reduction to be explored.
- Conditioning for long term storage such that compliance with mid term waste acceptance criteria (WAC) for disposal may be ensured to be considered
- The need for research and development activities to these ends to be assessed.

ILW
- Storage for decay purposes with a view to release from regulatory control before 2073, is due to the contents of long-lived radionuclides in general not considered an option for most waste groups belonging to this category of waste.
- Options for separation of short-lived components from particular waste groups could be considered, once re-assessment of waste groupings is complete.
- Options for carrying out further volume reduction to be explored.
- Conditioning for long term storage such that compliance with future acceptance criteria for disposal may be ensured to be considered
- The need for research and development activities to these ends to be assessed.

Special Waste
  - Conditioning must ensure feasibility of options for either an international solution or disposal in a Danish disposal solution for all waste groups.
  - Options for reprocessing of fuel (and return of fission-product waste component) to be explored
  - The need for conducting research and development activities to these ends to be assessed.

The re-assessment of the inventory will provide fundamental input to the identification, planning and conduct of future actions in the framework of the national progamme.

3.2. Inventory

The national inventory of radioactive waste comprises LLW and ILW (IAEA, GSG-1). The combined amount of radioactive waste is stored at Danish Decommissioning at Risø. Below, the amounts and combined activity of radioactive waste, presented per storage location (Table 2), is given with reference to the overview map of the Risø site:

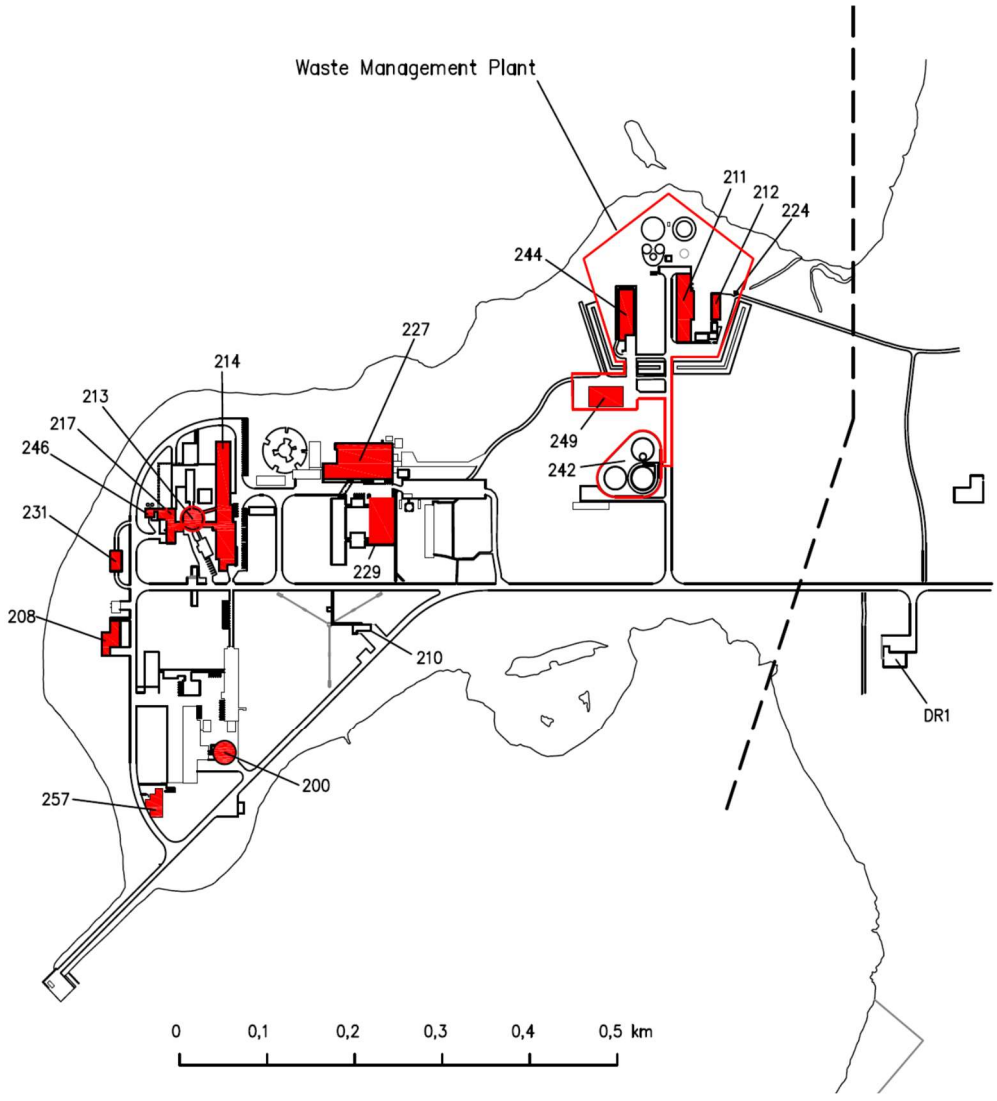

Figure 4, Map of the Risø Peninsula and site. The objects marked red resemble the building managed by DD. Each red building has a number attached, which corresponds to the building number in Table 1.

Building number	Danish designation	English designation
200	H-hallen (DR 2, reaktorhal)	DR 2 Reactor Containment Hall
208	Aktivt Laboratorium (A-lab)	Radiological Characterization Laboratory
211	Behandlingsstationen	Waste Management Plant (main building)
212	Tromlelager	Drum Storage (including drum press)
213	DR 3, reaktorhal	DR 3, Reactor Containment Hall
214	Kontorbygning og DR 3 AH-hal	Office building and DR 3 Active Handling Hall
217	DR 3, driftsbygning Inddampningsanlæg	DR 3 (auxiliary building) Radioactive water treatment
224	Lager for radioaktive væsker	Storage of Radioactive Liquids
227	Hot Cell	Hot Cell Facility
229	Teknologihallen	Fuel Fabrication Facility
231	Centralvejslager	Centralvej Storage
242	Tailingsbassiner og malmbunker	Tailings pools and ore heap
244	Lager for Lavaktivt Affald	Low Level Waste Storage
246	Bygning der rummer tanke til aktivt spildevand	Building including tanks for radioactive waste water
249	Mellemlager og Bufferlager	Intermediate Storage
257	Frigivelseslaboratorium (F-lab)	Clearance Laboratory

Table 1: List of buildings managed by DD. The location of each building on the Risø Peninsula is shown in Figure 4.

LLW and ILW storage

Radioactive waste stored at the Low Level Waste Storage (Building 244) and Intermediate Storage (Building 249) is predominantly LLW. Waste stored at the Drum Storage and Centralvej Storage (Buildings 212 and 231) is primarily ILW. Volumes and amounts of ore heaps and tailing pools (Location 242), are provided for informational purposes, bearing in mind that the ore has not yet been declared as radioactive waste.

Storage facility	Mass (tons)	Activity (TBq)
Low Level Waste Storage	~1,100	6
Intermediate Storage	1,605	234
Drum Storage and Centralvej Storage	~130	424
Taillings pools and ore heap	4,800	0.1

Table 2: Inventory of conditioned and unconditioned radioactive waste stored at Danish Decommissioning as of January 2020, classified as low and intermediate level waste (LLW and ILW).

Special Waste:
The inventory of ILW comprises a small amount of waste, termed “special waste”, primarily consisting of 233 kg (HM) of experimentally irradiated fragments of spent fuel, which underwent physio-chemical and metallurgical examinations in the years 1968-1990 and has a combined inventory of less than 600 TBq out of which about 35 TBq is longlived alfa-emitting nuclides. Heat generation is insignificant and active cooling is not required. In the combined inventory of radioactive waste, the alfa-emitting nuclides in the special waste constitutes approximately 90 % of the long-lived waste, while the remainder of the activity in the special waste comprises about 40 % of short-lived activity in the overall inventory.

Spent Fuel	Storage facility	Material	Mass/Volume	Activity
Core solution from DR 1	DR 3 building complex	Solution of 20% enriched uranyl sulphate in light water	4.9 kg U 15.8 l	28.4 GBq fission products 0.4 GBq actinides
Experimentally produced and irradiated fragments of spent fuel of power reactor type	The Centralvej Storage	Uranium oxide pellets mostly in zircalloy tube	233 kg U	533 TBq fission products 35 TBq Actinides

Table 3: Specification of the special waste, including the material composition and quantities with regard to mass/volume and activity as of January 2020.

The mass and material composition of the special waste remains unchanged since previous reportings (Table 3). Thus, the nuclide composition is overall the same with a small adjustment in the activity due to the nuclear decay; the fission products, ^{137}Cs and ^{90}Sr, and the actinides, ^{239}Pu and ^{240}Pu, almost exclusively account for the current activity of the Danish Reactor 1 (DR 1) liquid core solution.

Similar to the DR liquid core solution, the amount of experimentally produced and irradiated segments of spent fuel of power reactor type remains the same. Accordingly, the calculated activities are decay corrected to the datum of 01-01-2020 using the safeguard records and burnup scaling factors. The most notable fission products are ^{137}Cs, ^{90}Sr, ^{151}Eu and ^{154}Eu and actinide isotopes include ^{235}U, ^{236}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, and ^{241}Am.

3.2.1. Estimate of Future Waste

Radioactive waste from decommissioning of the nuclear facilities

The total volume of waste to be disposed of, once decommissioning is completed, was estimated in 2008[21] and 2011[22] to be in the range of 5-10.000 m^3, conditioned for disposal.

The estimates were based on the then specified decommissioning plans for the nuclear facilities at Risø. Since then, further plans for decommissioning, most notably of the waste management plant and associated storage facilities have been developed, and the decommissioning plan the Hot Cell Facility has been updated, taking into account the revised approach of demolishing the entire Hot Cell block.

These updates to plans have resulted in adjustments in the estimates for storage volume needed in the currently operating Intermediate Storage (building 249), as well as in the upgraded storage facility to be established following the provisions adopted in Parliamentary Decision B90/2018.

The currently anticipated requirement for storage volume in the upgraded storage facility amounts to ca. 15.000 m^3 waste conditioned for storage – including both institutional waste and decommissioning waste. The storage facility will be constructed with a storage capacity of 15.000m^3 + 25% and a possibility for future expansion of the storage volume.

In addition, ca. 2500 m^3 uranium ore, 900 m^3 concrete embedded tailings and 114 m^3 NORM material which is currently in Danish Decommissions possession will be placed in a building annex without climate control (the so-called cold barn).

Radioactive waste from institutional use

Institutional users of radioactive materials transfer a combined amount of radioactive waste of less than 10 tons per year to Danish Decommissioning. The radioactive waste

[21] https://www.ft.dk/samling/20081/redegoerelse/R4/633395.pdf
[22] https://www.dekom.dk/wp-content/uploads/publikationer/langsigtet-loesning/2011_slutdepot_forstudier_hovedrapport.pdf

mainly stems from research and industrial applications, but also includes disused ionizing smoke detectors from household applications, disused demonstration sources from schools etc. The use of radioactive material within the medical sector shows tendencies towards a widening of the field of use of radionuclides in medical applications combined with an increase in use of shorter-lived radionuclides, largely alleviating issues of radioactive waste management through decay.

Radioactive waste to be disposed of
The assessment of volumes and amounts of radioactive waste to be disposed of will be addressed in the framework for re-assessment of the management options concerning LLW and ILW, including the special waste.

3.2.2. Assumptions supporting Estimate

Radioactive waste from decommissioning of the nuclear facilities
Assumptions regarding the amounts of radioactive waste resulting from decommissioning of the nuclear facilities in the Risø area are delivered from each of the decommissioning projects. The assumptions are conservative estimates based on existing volumes of waste with additions of future volumes based on the latest updated decommissioning plans. For example, the estimates include the assumptions that large parts of the building materials, against all expectations, are contaminated and thus cannot be unconditionally released from regulatory control. In any case, decommissioning of the nuclear facilities is well underway, and the resulting volume of waste is no longer subject to significant uncertainty.

Radioactive waste from institutional use
The generalized scheme for radioactive waste management in Denmark, see Chapter 3 (section 3.1), is intended to generate an overall “flow” of radioactive waste supporting waste minimization and volume reduction, while ensuring that radioactive waste not suited for any other use ultimately is transferred to Danish Decommissioning. The regulatory limitation on storage time for radioactive waste by the licensees (maximum 1 year) mitigates build-up of significant amounts of radioactive waste at any other point in Danish society than at Danish Decommissioning.

Licensees are subject to regulatory requirements for keeping records of all stored and transferred radioactive materials, including radioactive waste. Likewise, DD is subject to the requirement of keeping records of all radioactive waste generated during decommissioning as well as radioactive waste received from institutional users.

Given the limited amounts of radioactive waste generated through institutional use, the inventory of radioactive waste managed by Danish Decommissioning therefore provides a robust estimate of the national inventory of radioactive waste at any point in time. Considering the future amounts of waste from institutional users, the estimates are conservative, assuming waste production to remain at the same level as the current – and even larger percentage fluctuations in the already very limited production will have minimal volume significance.

3.2.3. Uncertainties of Assumptions

Radioactive waste from decommissioning of the nuclear facilities

With decommissioning activities of the nuclear facilities drawing to a close, the number and size of uncertainties in estimates of radioactive waste arising from these activities are decreasing. For the remaining facilities to be decommissioned the uncertainties especially revolves around the degree of contamination of building material and thus the relative amounts of material that, in the end, can be free released. As the estimated volumes are based on conservative estimates, the assumption is that the uncertainties will lead to a smaller volume of waste than originally estimated.

Radioactive waste from institutional use

While production of radioactive waste from institutional use over the past decade or so has proven relatively constant, the increase in the number of cyclotron facilities installed at research and treatment centres poses a potential source of radioactive waste, once the shielding of such bunker-type facilities is decommissioned. The total number of cyclotron facilities currently in operation is five, and the number of planned facilities is two. One facility is in the planning stage for decommissioning, subject to assessment of radioactive waste generated during decommissioning.

Preliminary studies indicate that decommissioning may generate substantial volumes of activated concrete and steel waste. The activity concentrations of such materials are deemed overall low, and dominated by radionuclide inventories with relatively short half-lives, enabling storage and decay as a possible waste management route. The specific characteristics of this potential waste stream are still subject to study, and will be included in future projections for generation of radioactive waste, taking *inter alia* the expected life-spans of cyclotron facilities into consideration.

4. Waste Management

Danish Decommissioning (DD) is the main generator and responsible manager of radioactive waste in Denmark, and also has responsibility for pre-disposal management, incl. storage of waste from decommissioning of the nuclear facilities as well as other institutional radioactive waste generated in Denmark. The generalised framework for management of radioactive waste is illustrated in Figure 3 below.

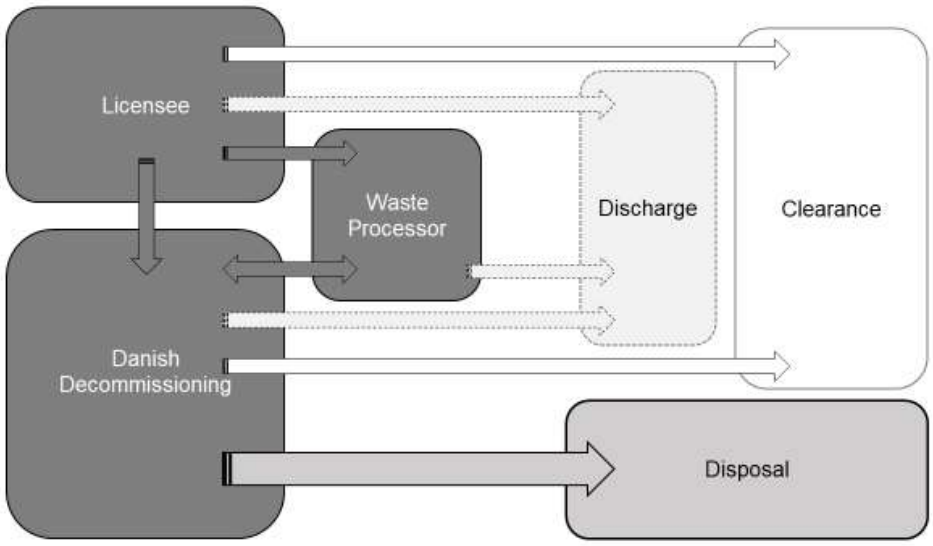

Figure 5, Generalised framework for radioactive waste management

Radioactive waste is defined in Executive Order 670/2019 as radioactive material with no foreseen use. As such, radioactive materials in liquid and gaseous form, with no foreseen use, is also radioactive waste. According to the provisions in Executive Order 670/2019, radioactive waste must ultimately be discharged or disposed of. Licensees may discharge radioactive waste suited for discharge according to the provisions in Executive Order 670/2019 or may transfer radioactive waste for further processing (which may lead to discharge, for instance by incineration), or treatment with the aim to reduce volume or with a view to re-cycle or re-use. Radioactive waste resulting from processing which is not suited for discharge must be transferred either for further processing or to Danish Decommissioning.

Danish Decommissioning in turn, within its remit of activities, works towards reducing the amounts of radioactive waste to be disposed of. Both licensees and Danish Decommissioning may release material, including waste, from regulatory control, if the criteria for release of material from regulatory control are satisfied. Licensees may store radioactive waste for up to 1 year with a view to release material upon decay, from regulatory control,

whereas Danish Decommissioning may store waste (also with the purpose of decay) up until the point in time, where a national disposal facility is available.

Radioactive waste produced as a result of activities in oil or gas industries, as a by-product of geothermal heat generation, at water treatment plants etc. are subject to the same regulatory regime as specified above. Radioactive waste from these activities is stored at facilities operated by the waste-generators, awaiting development of a final management solution for these types of radioactive waste.

National waste management organization
Danish Decommissioning (DD) was established in 2003 with the purpose of decommissioning the nuclear facilities at the Risø peninsula. Furthermore, Danish Decommissioning serves as the only end receiver of Danish radioactive waste and is responsible for managing and storing the waste (not including NORM). When waste is received from external (institutional) users, Danish Decommissioning takes over full responsibility for the waste.

Thus far, the main focus of activities has been on decommissioning. However, in the future, as decommissioning is nearing completion, focus will change, gradually turning Danish Decommissioning into an organization centered on waste management, responsible for safe storage of the waste, and co-responsible for the process leading to a disposal solution that must be in operation in 2073 at the latest according to Parliamentary Resolution B90/2018.

4.1. Radioactive waste management

Radioactive waste management in the general framework depicted in Figure 3 above, is with respect to the tasks undertaken by general licensees, limited to simple sorting, characterization, labeling and transfer to Danish Decommissioning. Radioactive waste received by Danish Decommissioning is managed according to the same provisions as radioactive waste arising from decommissioning, as presented below.

4.1.1. Waste management framework (Current practice)
Danish Decommissioning has established a waste management framework based on the prerequisites and goals for radioactive waste management presented below:

Prerequisites:

- Danish Decommissioning operates in compliance with the Operational Limits and Conditions for Danish Decommissioning in addition to other relevant requirements issued by the Danish authorities
- Danish Decommissioning additionally carries out radioactive waste management in accordance with international conventions, standards, recommendations and good practice

- Compliance with other relevant legislation in the areas of waste and environment
- Radioactive waste is packaged with the view to storage it at the Risø site.
- All relevant knowledge about the waste items is documented and stored in Danish Decommissioning´s Waste documentation System (WDS)
- For storage Danish Decommissioning uses the waste containers approved for storage in the existing storage facilities

The goals for Danish Decommissioning's waste management is to:

- Ensure a uniform management of the waste
- Free release as much material as possible from the waste
- Sort the radioactive waste in the best possible way for purposes of optimization of packaging, stability and waste minimisation
- Optimize packing of the resulting waste regarding degree of filling, material composition and taking into account doses to personnel.
- Through written instructions, directions and documentation requirements to ensure a final quality product of waste
- Ensure that work is planned in a way that it can be carried out with high regard for safety and with a high level of professional competence
- Make sure that the radioactive waste is well documented and traceable both now and in the future
- Take into account the interdependencies between different steps of (current) waste management, as well as future needs for management related to implementation of the long term goals expressed in Parliamentary Resolution B90/2019.

To this end, a set of specific waste management processes has been implemented, as described below.

4.2. Waste management methods

4.2.1. Waste registration and characterisation

Radioactive waste received from institutional users or produced by Danish Decommissioning during decommissioning activities is registered, described by material type, physical condition, weight, size, origin, degree of contamination, date of registration etc. If full characterisation is not possible when the waste item is received or produced, samples are taken for the purpose of later characterisation. All radioactive waste is packaged in containers suited for storage in the storage facilities operated by Danish Decommissioning.

4.2.2. Storage

The packed waste is transferred to one of five storage facilities depending on origin (decommissioning or institutional users/operations waste), dose rate, or needs to observe security requirements or safeguard provisions.

The general waste acceptance criteria for all storage facilities include:

- The waste must be stored in containers as specified for each storage facility.
- Stored containers must be kept closed
- Stored containers must be placed in a mechanically stable configuration
- Free liquids are not allowed in the waste containers
- Stored waste must not lead to pressure build-up that may harm the waste containers

For each storage facility, a list of container types allowed in that particular facility is specified. For some facilities, nuclide contents and dose rates are restricted.

4.2.3. Waste management methods applied to dry waste

Dry waste (i.e. metals, concrete, other building materials, equipment etc.) is sorted according to material type and origin. Waste items for which it upon screening is estimated that they may pass free release criteria is sent to the ISO 17025 accredited free release laboratory for the required procedures. Waste that cannot be free released is cut into sizes suited for the container types allowed in the desired storage facility and transferred to storage. No further conditioning is added.

Screening
Waste produced during decommissioning is screened and items that are considered to have possibility to pass clearance measurements is transferred to the clearance laboratory for testing.

Sorting
The waste is sorted according to material. Complex items may be cut and sorted into fractions of different materials if possible and if it can be justified in relation to the radiation doses that the staff may receive.

Cutting
Large pieces of waste are cut into the desired sizes using different hand- or automatized tools.

Compressing
Items with a large open volume (e.g. pipes) are pressed flat when possible in order to save volume. Waste from operations or external users are compressed into double layer drums.

Decontamination
Decontamination is generally done with the purpose of possible free release and resulting waste volume reduction. Danish Decommissioning has been using a variety of methods involving washing by hand, high pressure jets, blasting with different media such as metal, sand and glass.

Incineration/volume reduction
Combustible material that meets the requirements of the external contractor is transferred to incineration abroad. The produced dust and ashes are transferred back to Danish Decommissioning. The volume reduction presently achieved by incineration is around 98%. So far two batches of waste have been sent for incineration with the same contractor. A new contract was signed for each batch.

4.2.4. Waste handling methods applied to wet waste

Liquid radioactive waste has to be transferred to the solid state prior to packing and transfer to storage. Transformation into the solid state is ensured through evaporation. For inorganic solutions, the resulting sludge was previously cast in bitumen and stored in double layer drums. For organic liquids, the remaining sludge was previously embedded in an absorbing media such as dry cement, vermiculite or treated clay.
Following the initial decommissioning steps of the Waste Management plant, a new solution for stabilizing solid residues from liquids has to be developed.

4.3. Provisions pursuant of Parliamentary Resolution B90/2018

Since the adoption of Parliamentary Resolution B90/2018, the strategic focus of Danish Decommissioning has been on establishing a new, upgraded storage facility (NOL) which will replace the existing storage facilities for radioactive waste at Risø. A driving force for the decision to establish a new storage facility is the fact that the existing storage facilities, after several decades of operation, have been deemed inadequate to ensure safe storage of radioactive waste for an additional 50 years. Furthermore, three of the existing storage facilities at Risø are located only a few meters above present-day sea level, and continued operation of these facilities could pose an increased risk of flooding during storms as a result of generally rising sea levels due to climate change. According to Parliamentary Resolution B90/2018, all radioactive waste stored at Risø will be transferred to the upgraded storage facility, also designed to mitigate risks associated with climate change, and will remain stored there until a disposal solution for the waste is operational.

Danish Decommissioning's present plans for waste management are described in "Strategy for the work of the Danish Decommissioning after the adoption of parliamentary resolution B90", December 2018 (in Danish only), with a later addition regarding different phases related to the upgraded storage facility.

Overall, two phases of waste management is envisaged, covering the short term and the mid- to long term perspectives. In the shorter term, in the *establishing phase* the upgraded storage facility is established and waste transferred with a minimum of repackaging and in the mid- to long term, the *operational phase*, two types of waste management will be carried out:

A. Tasks related to storage activities such as periodic inspection of waste units and, if necessary, repackaging. The outcome of radioactive waste management activities must remain reversible until WAC for further management/disposal have been defined.
B. Waste management activities related to long term goals of Parliamentary Resolution B90/2018, including disposal: development of WAC for disposal, packing and conditioning in accordance with WAC for disposal

The outline of the establishing and operational phases, including overall provisions for establishing and developing WAC for the upgraded storage facility and subsequent disposal solution, is presented below

Establishing phase:
In the short term, focus is on the planning and construction of the upgraded storage facility and the management and transfer of the radioactive waste. The upgraded storage facility must be designed and constructed in a way to facilitate storage of all radioactive waste already in storage by Danish Decommissioning, as well radioactive waste produced through decommissioning of the remaining nuclear facilities at the Risø site and radioactive waste arising from institutional uses for the entire operational phase of the upgraded storage facility.

For transfer of waste into the upgraded storage facility, general waste acceptance criteria for the establishing phase take into account the requirement to facilitate storage of all radioactive waste already in storage by Danish Decommissioning. The WAC for the establishing phase are specified with the aim of ensuring safe transfer and storage of the existing radioactive waste, and to facilitate safe conduct of all subsequent waste management operations envisaged to take place in the operational phase.
Waste acceptance criteria for the establishing phase of the upgraded storage facility are continuously elaborated and *inter alia* specify types of containers accepted, requirements for container integrity (no signs of physical damage, corrosion etc.), physiochemical form of the packaged radioactive waste (e.g. no free standing liquids), dose rate limitations etc., as specified below.

- Only waste packed in one of these three container types is allowed: DD steel containers,10’ ISO containers, half height, and DD jumbo containers
- The maximum weight of filled 10’ ISO containers is 21 tons
- The maximum weight of filled DD steel containers is 13 tons
- The maximum weight of filled jumbo containers is 100 tons
- The outer surfaces of the waste packages must be free of radiological contamination
- The outer surfaces of waste packages must be without visible signs of corrosion
- The waste packages may not contain free liquids
- Maximum dose rate allowed on the surfaces of the waste packages is 2mSV/h
- Waste packaged in drums showing no signs of rust stains or - holes is allowed inside 10’ ISO containers without further conditioning

- Waste packaged in drums showing stains and/or rust holes is allowed inside DD steel containers if the steel containers are backfilled with DD backfill material (consisting of 1-7 mm carbonate balls covered in cement)
- All waste packages must be marked with a lasting identification plate to allow for unique identification
- The data registered for each waste package must fulfill the requirements of Executive Order no. 670 of 1 July 2019 on Use of Radioactive Substances as well as other relevant laws and regulations

Waste that is not yet packaged will be packed according to the waste acceptance criteria for the upgraded storage facility. Waste currently stored in waste containers not accepted in the upgrade storage facility, will be repackaged into one of the three accepted container formats.

Operational phase
In the area “Waste Management” (figure 2), the framework for developing mid- to long term strategic objectives will take into account the overall framework for re-assessment of the inventories for LLW and ILW, including the special waste, as described in section 1.7. This will enable charting out needed as well as optional radioactive waste management steps, facilitating continued probing for international solutions viz-a-viz the special waste, as well as provisions for timely implementation of storage and predisposal management steps designed to meet technical demands for disposal. Requirements for research and development related to these steps will be described, and the interdependencies between management steps of the radioactive waste identified.

Waste acceptance criteria for the operational phase are expected to be adapted according to the mid- to long term objectives for waste management, such that waste introduced to the upgraded storage facility may need to be managed (segregated, sorted, volume reduced, stored with a view to decay etc.) and packaged according to updated WAC for the operational phase, all with a view to facilitate conditioning for a final management step, i.e. disposal, options for export, etc.

In relation to the area “Disposal Solution”, the level of radioactive waste characterization needed at an early stage will be addressed, in order to explore disposal concepts and to demonstrate safety though production of a robust safety case and WAC for disposal. The need for providing input to the area “Geology and Siting” will be taken into account.

As such, radioactive waste management in the mid- to long term will effectively ensure the underpinning of all operational steps needed to accomplish the goals set out in Parliamentary Resolution B90/2018.

5. Development of long term solutions

The achievement of the end goals for management and disposal of radioactive waste as presented in Parliamentary Resolution B90/2018 requires development of long term solutions in both the technical and the socio-economic areas of the programme.

For the technical areas, development of long term solutions requires identification of technical requirements needed to complete individual steps. In developing and implementing the necessary technical solutions, the adequacy of available techniques needs to be examined, and the need for conducting research and development to satisfy technical needs not covered by available techniques, must be assessed. The sufficiency of a chosen technical solution may be subject to demonstration prior to actual implementation of the solution.

For the socio-economic areas, development of long term solutions requires definition, coordination and implementation of processes (e.g. stakeholder engagement, public outreach, financing and costing procedures), which do not necessarily rely closely on technical solutions, but to a high degree depend on receiving input and providing feedback to efforts in other areas.

In the following sections, an overview of the efforts needed to develop long term solutions in each area are presented with a primary focus on the technical requirements for implementation in the technical areas and on the input and feedback mechanisms envisaged for the socioeconomic areas.

5.1. Waste management:

Following the provisions of Circular no. 9654, Danish Decommissioning is responsible for planning and documenting the management of radioactive waste, taking into account:

- internationally utilised management methods; and
- existing and planned management of existing or planned waste streams, including;
- existing technical solutions until disposal,
- future solutions to be developed before disposal and after closure

In this process the interdependencies between all steps in the generation and management of radioactive waste, as well as the plans for maintaining safety in the post-closure phase of a disposal solution must be taken into consideration.

To this end, Danish Decommissioning has initiated the process of identifying needs for research, development and demonstration in the framework of the overall strategy for waste management, described in Chapter 4. The basis for this process is the outcome of the re-assessment of inventories and management options concerning LLW and ILW, including the special waste (cf. Chapter 3), from which the specific technical solutions needed to achieve radioactive waste management goals will be specified along with requirements for research, development and demonstration needed to ensure availability of such technical solutions.

Following the identification of tasks, the specific plans for their conduct will be elaborated. The identification of needs for research and development as well as demonstration activities (proof of concept) will follow the sequence outlined in the overall waste management strategy, referring to short term as well as mid to long term objectives.

5.1.1. Short term (establishing phase)

For the short term, the following priorities have been established:

- Identification of technical requirements for safe transfer and storage in upgraded storage facility
- Demonstration of existing/available technical solutions to enable safe transfer and storage in upgraded storage facility

No research and development activities have been deemed necessary to achieve these goals in the short term. The focus for the short term strategy is the construction of an upgraded storage facility and transfer of radioactive waste packaged in a manner such as to ensure safe storage and feasibility of future management steps. The technical requirements for waste packages and for the upgraded storage facility have been defined with a view to ensure safe transfer and storage of waste, and at the same time facilitate simple means of demonstrating the adequacy of the solution, both from a safety perspective and from an operational point of view.

The upgraded storage facility is currently in the planning and design stage. The selection of technical solutions for both the building structure itself as well as equipment and installations needed for its operation, has been based on a preference for widely applied industrial standard off-the-shelf solutions.

Following the tender[23] outlined for the project, the upgraded storage facility for existing waste and the future waste generated until 2073, will include a waste reception facility; a facility for handling, analyzing, characterizing, conditioning and packing the waste; an administration building and possibly an exhibition facility for approximately 110-120 people in order to increase stakeholder insight.

[23] Available at the Danish Decommissioning website: https://www.dekom.dk/wp-content/uploads/2019/10/2019_NOL_Udbudsmateriale.pdf

The main storage building is designed to ensure safety of the waste as well as future workers, applying remotely operated traverse cranes, lifting aisles and container guide systems, operating in a sealed part of the storage volume with no direct access for personnel. Service and maintenance areas are designed and constructed to ensure access without the need to access the main storage area, and other systems, structures and components are designed and selected to ensure long term reliable, low-maintenance operation. These targets are met primarily through selection of off-the-shelf solutions with proven long term service records in the shipping, storage, transport etc. industries. The perimeter wall dimensions will be 40 cm thick concrete and the floor level will be placed at least 4 meters above sea level to mitigate risk of flooding. Part of the storage facility will be constructed as a closed and fully climate controlled building to ensure a uniform and stable storage environment, while other storage building(s), reserved for storage of ore and residual tailings materials, will be constructed as simple covered structures without climate control (so-called “cold barn”).

The present target for the commissioning of the upgraded storage facility is august 2024. Construction is expected to commence in 2022 after the completion of the initial phase environmental impact assessment, municipal planning, local planning and design, construction approval by the regulatory authorities, as well as construction budget approval by Parliament. A public hearing and an ESPOO hearing are planned to take place in September/October 2021. Additionally, the establishment of an upgraded storage facility may be subject to the procedures following article 37 of the EURATOM Treaty. The safety assessment for the storage facility is in preparation and will form the basis for application for both the construction license application and the operating license application for the storage facility. Upon commissioning (granting of operating license), the waste can be transferred from the existing waste management and storage facilities which may then be decommissioned and removed - or decontaminated and released from regulatory control - in accordance with Parliamentary resolution B48/2003.

As part of the basis for application for the construction license as well as the operating license application the upgraded storage facility, all installations, equipment etc. will undergo trial runs. The trial runs will provide part of the documentation demonstrating that the upgraded storage facility has been established and can be operated in a safe manner.

5.1.2. Mid to long term (operational phase)

For the mid to long term, the following priorities have been established:

- Completion of a fully operational upgraded storage facility, including waste management facilities etc.
- Further characterization and verification of inventory of LLW, ILW and “special waste”
- Identification of technical solutions needed to carry out waste management options identified in strategy for management of LLW, ILW and “special waste”
- Demonstration of existing/available technical solutions

- Identification of research and development required to achieve required technical solutions
- Implementation of research and development

In the mid to long term, requirements for satisfying the objective of long term safety for storage of the radioactive waste in the upgraded storage facility will be identified on the basis of the outcome of the re-assessment of the LLW, ILW and special waste, as described in Chapter 3. As part of the re-assessment, technical requirements and solutions for further characterization of the waste will be defined.

The identification of technical solutions needed and subsequent research, development and demonstration activities required to achieve this, will for LLW take into consideration options for sorting, segregation, decay storage and volume reduction. For ILW, technical solutions for sorting and segregation must be analysed with a view to explore potential for minimizing volumes for disposal.

For the “special waste” the technical requirements and needs for research, development and demonstration necessary to realize options for reprocessing (abroad), export with the purpose of disposal, or inclusion in a Danish disposal solution, must be identified and integrated in the implementation of the national programme at an early point in time to ensure a timely availability of the chosen management option. For this purpose, Danish Decommissioning is in contact with an international corporation with expertise in fuel reprocessing and conditioning with the aim of exploring existing possibilities for processing-/conditioning of the special waste and identifying the technical prerequisites for pursuing other management options envisaged for the “special waste”.

With regard to the exploration of exporting the special waste with the purpose of disposal, the Danish Ministry of Foreign Affairs has conducted consultations with a number of OECD member countries in order to establish whether legal, technical and political conditions exist for the conclusion of a bilateral agreement on disposal of the special waste. So far, this has been found not to be the case.

As part of Parliamentary Resolution B90/2018, the Ministry of Foreign Affairs will continue to consult with potential countries for a bilateral agreement on the disposal of the special waste, while observing the requirements in Article 4(4) of Council Directive 2011/70/EURATOM. The Ministry of Foreign Affairs will report the outcome of consultations to the Ministry of Higher Education and Science.

Consultations for a bilateral agreement on disposal of the special waste will neither delay nor postpone the development of a disposal facility on Danish soil. From Parliamentary Resolution B90/2018 follows that the consultations of the Ministry of Foreign Affairs will be terminated if no agreement has been reached by the time when a proposal to build and operate a disposal facility is presented to Danish Parliament.

For the storage period in the upgraded storage facility, any pre-disposal management of LLW, ILW and “special waste” must ensure that further management remains possible, and must be compatible with the implementation of a disposal solution.

Danish Decommissioning participates in the EURAD programme, the Strategic Studies Work Package (SS WP) on waste management routes. One of the tasks under the “Routes” WP is investigating the potential of shared solutions, both regarding pre-disposal and disposal. The project is of particular interest for small inventory member states (SIMS) with only limited amounts of long lived waste.

Danish Decommissioning closely follows the work conducted in several work packages under the EURAD programme, including “Research, Development and Demonstration”, “Strategic Studies” and “Knowledge Management”, as a source of input to the design of national Research, Development and Demonstration programs. Danish Decommissioning also partakes in the ERDO-WG, following projects on characterisation of legacy/historic waste and on borehole disposal solutions.

For the Waste Management area, the essential deliveries in the national programme over short, mid and long term periods are summarised below:

Short to mid term

1. Construction and commissioning upgraded storage facility and transfer of waste
2. Reassessment of waste classification and further characterisation of radioactive
3. Evaluate and select predisposal management options taking into account interim targets and decisions presented in Parliamentary Resolution B90/2018
4. Identify technical solutions needed to carry out predisposal management options and conduct research required to establish technical solutions
5. Conduct of predisposal management operations identified in 3.

Long term

6. Develop WAC for disposal and disposal concept in an iterative process
7. Conduct predisposal management in accordance with WAC for disposal
8. Transfer waste to disposal facility.

5.2. Geology and Siting

The importance of integrating stakeholder views in the siting process, is taken into account through focus on local communities and their respective municipal administrations. The purpose of this focus will be to explore the options for engaging in a partnership dialogue. Local communities will be invited by the Ministry of Higher Education and Science to partake in an unconditional process to assess their interests and stakes as well as the opportunities arising from the disposal facility.

The partnership is intended to be a long term engagement between the Ministry of Higher Education and Science and potential disposal facility hosts with an aim to identify the conditions which must be fulfilled to ensure that a disposal facility will not be at odds with the aspirations and concerns of local communities. The areas of stakeholder engagement are elaborated in Section 5.1.5 below.

5.2.1. Short term

Parliamentary Resolution B90/2018 presents the possibility of choosing different disposal solutions for different waste classes albeit located at the same geographical site. In line with Parliamentary Resolution B90/2018, The Geological Survey of Denmark and Greenland (GEUS) is currently performing a review of existing data on Danish geology extending to depths of 500 m. Reports on the results are expected in the first quarter of 2021. The outcome of this survey will be combined with results presented earlier by GEUS on the geology to depths of about 100 m[24].

The combined surveys will provide geological parameters for further identification of suitable geologies for siting, taking into account options for disposal solutions utilizing different geological levels at the same geographical site.

The outcome of the short term geological studies will directly constrain the framework for efforts in the area “Disposal solutions”.

Likewise, the outcome or work from the area “Stakeholder engagement”, including the options for voluntary and active participation of local communities in the process of developing a disposal solution will provide constraints and define research, development and demonstration tasks to be carried out in the area “Geology and siting”, both in the short and mid term perspectives.

5.2.2. Mid term

The overview of geological features relevant in the context of siting of a disposal solution will form part of the framework for defining technical solutions and subsequent specific research and development required to establish disposal solutions in a variety of suitable geological settings identified in the survey. For the site investigations planned for the mid term, the properties of geological formations will be examined in further detail, potentially through drill core studies, with the aim of verifying available information and collecting further data of geologically relevant parameters.

In the longer term, a smaller number (minimum 2) of locations may be subject to detailed studies, carried out as *in-situ* studies potentially including drilling or underground laboratory investigations. The exact scope and format of studies carried out at this stage will depend on a variety of parameters, including choice of management route for all waste classes, in particular the “special waste”, the preferred disposal solution, the geological characteristics of the site(s) in question etc.

[24] GEUS reports can be found at: https://www.geus.dk/natur-og-klima/land/deponering-af-radioaktivt-affald/studier-og-rapporter

The outcome of site investigations and detailed studies will feed into the work carried out in the area “Disposal solution”, providing the framework for further definition of requirements for engineered barrier systems.

For the Geology and Siting area, the essential deliveries in the national programme over short and mid term periods are summarised below:

Short term

1. Comprehensive review of existing data on Danish geology extending to depths of 500 m.
2. Explore partnership models with interested municipalities/local communities
3. Designation of suitable geologies in view of possible disposal concepts satisfying generic safety criteria and partnership interests if possible

Mid term

4. Site investigation of multiple sites
5. Designation of most relevant sites for detailed studies
6. Site studies – minimum 2 sites

5.3. Disposal solution

Development of a disposal solution will take place in an iterative manner, taking into account results from the technical areas “Waste management”, “Geology and siting”, but will also be shaped according to the outcomes of work from the area of “Stakeholder engagement”, in particular the options for municipalities to venture into voluntary projects for development of disposal solutions that are both safe and locally acceptable.

5.3.1. *Mid to long term*

For the technical aspects, development of a disposal solution will proceed through a series of steps, exploring the feasibility of generic disposal solutions, technical requirements for particular types of disposal solutions and specific requirements for the designated types of disposal solutions. The overall proposed sequence is outlined below:

- In analogy to previously conducted studies[25], the outcome of the geological studies carried out in the short term (cf. section 3.1.1), will provide the generic geological features to be considered in an initial study of the feasibility of combining natural and engineered barrier systems to form a robust disposal solution satisfying the basic criteria for safety. The feasibility study will take into account the results from re-assessment of the inventory intended for disposal.

[25] https://www.dekom.dk/wp-content/uploads/publikationer/langsigtet-loesning/2011_slutdepot_forstudier_hovedrapport.pdf

- In conjunction with the site investigations (cf. 3.1.2), the particular technical requirements for waste conditioning, packaging and engineered barrier systems for establishing such generic disposal solutions will be developed.
- Specific requirements for the disposal solutions considered at designated sites for detailed studies will be further developed based on the above generic studies.

For the Disposal Solution area, the essential deliveries in the national programme over mid and long term periods are summarised below:

Mid-term

1. Designation of possible disposal concepts in view of suitable geologies
2. Proposal for one or more specific type(s) of disposal solution(s) to be established
3. Planning act
4. EIA Plan assessment and EIA

Long-term

5. Safety Case
6. Construction Act
7. Construction of disposal facility incl. surface facilities for waste management
8. Licensing and commissioning (from 2073 at the latest)
9. Operational period
10. Closure

5.4. Organisational Framework

Until 2018 Danish Decommissioning was expecting to terminate operations around 2023, when the tasks within the scope of Parliamentary Resolution B48/2003 were to be completed. In this situation, the prime organizational focus for Danish Decommissioning was the challenge in maintaining the necessary competences as long as they were needed. The Operational Limits and Conditions for Danish Decommissioning specify a detailed set of competences that key staff in Danish Decommissioning must have or obtain in order to undertake these tasks. These include competences in radiation protection, quality assurance, knowledge of nuclear facilities and nuclear security, safety assessments, handling of radioactive materials etc.

In line with these provisions, Danish Decommissioning has built up specialized competences on decommissioning since the formation of the organisation in 2003. Competences on day-to-day waste handling and storage have been present in the organization for decades and maintained since Danish Decommissioning took over responsibility for radioactive waste management from the former Risø Research Centre. As no universities in Denmark offer specialized education in radioactive waste management and radiation protection tailored for the needs in decommissioning, Danish Decommissioning has developed its own theoretical and practical education programs suited for new staff with a background in technical or natural sciences.

The competences and staff needed to ensure safe transfer and storage of waste to the upgraded storage facility are thus covered by the capacity of the staff currently employed at Danish Decommissioning.

With the adoption of Parliamentary Decision B90/2018, Danish Decommissioning was given a wider remit of tasks, extending activities over a longer perspective of time. It therefore remains essential to be able to attract and maintain the necessary competences, also in a longer term perspective, in order to complete the newly assigned tasks. Maintaining skills and competences is a part of Danish Decommissioning's overall strategy for waste management, cf. Chapter 2.

The transformation of Danish Decommissioning from an operations oriented decommissioning organisation into an entity responsible for both routine operational (long term storage) tasks and long term planning and developmental task, requires a focus on the necessary staffing and competences, both in the short, medium and longer term perspective. Danish Decommissioning´s considerable knowledge and strong competences in decommissioning, including handling and storage of decommissioning and institutional waste, as well as involvement in pre-feasibility studies for disposal following Parliamentary Resolution B48/2003 and development of concepts for long term storage form the platform for planning and implementing this transformation.

5.4.1. Short term

In the short term (2021), Danish Decommissioning will develop an overall waste management plan in cooperation with an international organization with experience in safety analyses as well as site selection. Such collaboration will also strengthen the knowledge level internally. The desired overall output from the cooperation is listed below:

- A full project overview
- A GAP analysis on knowledge/needed knowledge of the waste. A special focus will be on historical waste.
- A GAP analysis on the waste routes for radioactive waste in Danish Decommissionings management system.
- A GAP analysis on data needed in order to decide on a disposal concept, develop WAC, and develop a robust safety case
- How to acquire the needed data. Characterisation techniques, technology etc.

The associated required staffing, skills, competence, resources needed in Danish Decommissioning for the first coming years and later in the projects will be detailed as part of this project.

5.4.2. Mid term

So far, Danish Decommissioning has not experienced problems in recruiting new staff – but there is an awareness that it may be a challenge in a longer term perspective, when decommissioning has come to an end and the organization will need to adapt to the task

of long term waste management and development and implementation of a disposal solution.

Once all decommissioning activities have ceased and release of the site from regulatory control is complete – there will be a reduction in the size of the organization needed to operate a storage facility. A previous study has estimated that a total number of 15 persons will be needed. However, specialist competences on waste management, radiation protection, QA etc. will still be needed. Staffing and competences needed in the organization for developing and implementing a disposal solution will require careful analysis of tasks, approaches to solve these tasks, and long term planning of how to meet staffing and competence requirements.

5.5. Stakeholder engagement

Public participation in the siting of a disposal facility as well as in the overall issue of radioactive waste management is enshrined in Parliamentary Resolution B90/2018, sections VI and VIII. Thus, public participation and stakeholder engagement will be encouraged continuously using e.g. the existing communication platform and infrastructure including the National Contact Forum, the Panel of Independent Experts as well as dedicated national websites as outlined in Section 2.4. As is presently the case with the decommissioning (cf. section 2.4.1) the forthcoming communication effort will address all aspects of the programme and provide access to all relevant documentation in accordance with the Danish legislation on public access to information. Over time, the means of communication and mechanisms of engagement may be adapted to suit the context and local dialogue preferences in the most appropriate way.

5.5.1. Short term

In the short term, a number of initiatives relating to the outcome of efforts in the area “Geology and Siting” will be launched, including:

- Municipal authorities and local communities will be consulted and invited to participate in a dialogue to discuss a partnership covering all aspects of the siting of a disposal facility.
- Following completion of the review of existing data on Danish geology, a matchmaking process will take place to possibly combine an interested local community and a potentially suitable disposal facility site. The aim is to develop a partnership to jointly investigate technical, environmental and socio-economic aspects of the siting process.
- In addition to participation and hearing requirements following from Danish law, the stakeholder community will continue to be served by the contact forum instrument as well as the communication platform already in place. It is the intention to further develop and customise the communication activities in dialogue with stakeholder representatives and local authorities.

The potential for all municipalities displaying an interest in participating in the process, to be included will be assessed in light of the objective to develop a disposal solutions that is both safe and locally acceptable. The aim of local engagement is to ensure transparency and intricate integration of stakeholder views and wishes in the process for both siting and development of a disposal solution. The integration provides the necessary inclusion of stakeholder interests in key decision points related to the implementation of the programme.

5.5.2. Mid to long term

Stakeholder engagement and partnership dialogue will be further elaborated on the mid to long term of the development of a disposal solution. The instruments to facilitate dialogue are expected to be increasingly operated by local stakeholder communities. Building on the increasing knowledge of local society regarding the issues surrounding the disposal solution, the intention is to expand and consolidate trust in the dialogue to derive at a detailed assessment of the consequences as well as opportunities flowing from the siting, construction and operation of a disposal facility. The purpose of the assessment is to establish a hierarchy of issues of concern for local stakeholders which may provide the basis for an incentive programme to target main concerns deriving from the disposal facility project.

6. Financing and Costing

Radioactive waste in Denmark mostly derives from activities of state-sponsored nuclear facilities on the Risø peninsula in the years 1957-2000. No nuclear power production takes place in Denmark. There is no direct source of tax revenue from nuclear waste producers to contribute to cost coverage of the national programme for management of radioactive waste. From the polluter-pays-principle follows that the Danish state must cover the financial costs relating to the national programme.

Application waste producers are subject to management fees upon delivery of waste to Danish Decommissioning. Fees are kept at a modest level in order to preserve the incentive to waste delivery[26]. The volume of application wastes is limited and is estimated to become even lower as the use of radioactive substances become more efficient or even substituted by other agents.

The financial resources for Denmark's national programme for the management of radioactive waste are derived from reserve fund allocations on the Financial Act adopted annually by Danish Parliament.

The financing system to secure the financing of the management of radioactive waste in Denmark has been established in two incremental stages:

1. The decision in 2003 to begin the decommissioning activities of Danish Decommissioning cf. Parliamentary Resolution B48/2003
2. The decision in 2018 to begin the upgrade of storage facilities of Danish Decommissioning and to begin the process towards the implementation of a disposal facility no later than 2073, cf. Parliamentary Resolution B90/2018.

In addition, financing relating to the competent national authorities and R&D activities are covered by allocations on the operating budgets of the various government agencies involved in the national programme.

In the following section, the financing system of the national programme will be described in relation to the areas and deliverables which are enshrined in the national programme, pls. refer to Figure 5 below.

[26] In 2019, management fees from application waste producers made up DKK 3 million, or 3.2 pct., of the total income of Danish Decommissioning.

6.1. Financing system of the national programme

The financing system covers the following areas:

Technical areas:
- Waste management
- Geology & siting
- Disposal solution

Socio-economic areas:
- Organisational framework
- Stakeholder management
- Economical & financial issues

6.1.1. Technical area: Waste management

Waste management includes the facilities upgrade at Risø, the probing for an international solution and the process moving from upgraded storage to predisposal to disposal. Danish Decommissioning is the waste management organisation responsible for operations to maintain and develop the national programme. The operating expenses of Danish Decommissioning are covered in § 19.61.03 of the Financial Act. Decommissioning projects are covered by installments from reserve fund § 19.11.79.70 in the Financial Act. This reserve fund was established in 2003 as a consequence of Parliamentary Resolution B48/2003.

Expenses relating to the upgrading of storage facilities and projects relating to the predisposal and disposal phases of the national programme are covered by installments from reserve fund § 19.11.79.71 which was established in the Financial Act for 2019 following Parliamentary Resolution B90/2018.

6.1.2. Technical area: Geology & siting

Expenses relating to geological research and siting investigation activities are financed by an allocation from reserve fund § 19.11.79.71. The allocation is installed in the budget of Geological Survey of Denmark and Greenland (§ 29.41.01.20 of the Financial Act) which is assigned the role of operator of geological and siting research in the national programme. Geological Survey of Denmark and Greenland is a self-governing and independent research institution under the Ministry of Climate, Energy and Utilities.

6.1.3. Technical area: Disposal solution

Danish Decommissioning has been assigned the task to develop the technical conditions and the design of the disposal facility. The task is enshrined in § 19.63.03 of the Financial Act and will be consolidated further in an update of circular 64 of 3 September 2012, mentioned in chapter 2 above. Funding for this purpose will derive from reserve fund § 19.11.79.71.

6.1.4. Socio-economic area: Organisational framework

The organisational framework consisting of the waste management organisation for storage, predisposal and disposal is financed through the operating budget of Danish Decommissioning.

The Danish Agency of Higher Education and Research is acting as the principal of Danish Decommissioning and supervises management priorities through the instrument of an annual target and performance plan[27]. The target and performance plan is revised and adjusted in an on-going dialogue between the Agency and Danish Decommissioning. The CEO of Danish Decommissioning enters a personal performance contract with the Agency on the basis of the approved target and performance plan.

6.1.5. Socio-economic area: Stakeholder engagement

Stakeholder engagement is organized and performed in the communication infrastructure described in Section 1.5 above. The Agency of Higher Education and Research has the responsibility for organizing and coordinating stakeholder initiatives and processes with Danish Decommissioning. The competent regulatory authorities and other entities will be involved as per the issues and special competences to be included in stakeholder communication. Stakeholder dialogue at the local level will be designed in a participatory process to allow for local communication needs and preferences to determine the structure and activities of the dialogue. The dialogue structure will strive to achieve maximum flexibility during the entire duration of the programme.

6.1.6. Socio-economic area: Economic and financial issues

In the following, the cost assessment methodology (hypothesis, inputs & boundary conditions) will be described relating to 1) decommissioning activities and 2) upgraded storage and disposal facilities.

Decommissioning activities

The cost assessment of the decommissioning of the nuclear facilities on the Risø peninsula is performed according to a target of complete decommission to greenfield status over a period of twenty years (2003-2023).

Costs are assessed according to two groups of activities: a) Basic expenses relating to the operation, security and maintenance of Danish Decommissioning; b) Project expenses relating to planning, investment and execution of decommission projects.

Cost assessment is laid out in Parliamentary Resolution B48/2003 stating annual expenses over the 20-year decommissioning project period. Estimations of project expenses include a buffer of approx. 31 pct. of total decommissioning costs to allow for unforeseen costs. Total decommissioning costs are estimated at approx. DKK 1,120 million (2003 net present values). Decommissioning activities are expected to be completed by 2025.

[27] (available in Danish at: https://dekom.dk/en/2020/01/08/hvad-skal-vi-naa-i-2020/)

Upgraded Storage facilities
The specifications of the upgraded storage facilities are described in depth in a consultancy report: *Safety, economy and operation for a Danish long-term storage facility for radioactive waste* (2016)[28].

The cost assessment of upgraded storage facilities is targeting the implementation of an upgraded storage facility on the Risø location by 2025. The assessment of construction costs includes: a) Direct construction expenses, b) Construction site management expenses and c) Supervision/counselling expenses. A buffer to cover unforeseen expenses is estimated at 15 pct. of total construction costs.

In Parliamentary Resolution B90/2018, the construction costs of upgraded storage facilities were estimated at approx. 171 million DKK (2017 net present value) which included the following cost items:
- Storage facility
- Inspection area
- Loading/unloading space.

Existing facilities at Danish Decommissioning that will continue to be used or upgraded as part of the upgraded storage construction programme include:
- Fencing, perimeter guarding system and security gate
- Workshop and conditioning facilities
- Office space
- Roads and parking space
- Garages.

A consolidated construction budget is currently under scrutiny and will presented to Parliament for approval in 2021.

A visitor's centre is currently under consideration and may be included in the storage facility at a later stage.

Disposal facilities
The cost assessment of disposal facilities is based on a pre-feasibility study[29]. The pre-feasibility studies outlined 18 different disposal facility designs which were assessed according to the following items to be covered by the cost estimates:
- Acquisition of area
- Additional facilities at the disposal facility
- Construction
- Operation
- Closure

[28] https://ufm.dk/en/newsroom/issues/radio-active-waste/english-material/cowi-rapport_august_2016.pdf
[29] https://www.dekom.dk/wp-content/uploads/publikationer/langsigtet-loesning/2011_slutdepot_forstudier_hovedrapport.pdf

- Monitoring

The design of the disposal facility remains to be decided. The cost of the disposal facility has been calculated using a conservative estimate of the disposal facility design. As a consequence, cost estimation will be updated and further elaborated when a disposal facility design is decided and further specified for cost assessment purposes.

General assumptions for cost item estimates are summarized below:

Acquisition of area
It is considered that the land acquired for the disposal facility is located in a rural scarcely populated area. Depending on various conditions, such as land use, location and quality of land, etc., the square meter price will vary significantly.

Additional facilities at the disposal facility
The additional facilities are considered to be the same for all concepts and are thus treated once for all. It is assumed that the additional facilities at the disposal facility are established based on containers and lightweight steel structures or similar inexpensive solutions.

Construction
Construction costs include: detailed design, invitation to tender and field investigations. Construction costs are determined based on bills of quantities (BoQs). The cost estimates are based on bids for similar projects and on actual price quotes, in order to reflect market prices.

The market situation may be considered by assuming a general uncertainty of 15 pct. to 20 pct. on all price estimates related to the disposal facility structures. 17.5 pct. are taken as plus/minus variation on the most likely costs.

Operation
It is estimated that the disposal facility will operate an active period of 31 years of which the first year is considered an initial filling year in which additional operational costs have to be taken into account. It is considered that the initial filling period, where the bulk waste amount shall be placed in the facility, lasts for one year. Hereafter, it is assumed that the active operation continues for 30 years with an inbound waste flux of approx. 8 m^3 per year. For the cost estimate it is assumed that the waste is supplied, packed and ready for deposit, i.e. the cost estimate excludes packing, transport, etc.

Due to the 31 years of operation, the total operational costs are very sensitive to assumptions concerning staffing and salaries. For the determination of the most likely price it has been assumed that the basic operation during 31 years is realised by a permanent staff that is hired at certain, individual annual salaries (incl. social charges, etc.). For the initial filling period it is assumed that additional external personnel is hired from a contractor at much higher unit prices for the various (short-term) jobs. The overall uncertainty for the

operation costs is considered by using minimum and maximum percentages of the most likely costs of 75 pct. and 150 pct., respectively.

Closure
In correspondence with the construction costs, closure costs are determined by means of BoQs based on experience from recent comparable projects and actual price quotes. Thus, the general uncertainty of 15 pct. to 20 pct. on all most likely estimated costs also applies to the closure. 17.5 pct. are taken as plus/minus variation on the most likely costs.

Monitoring and institutional control
Monitoring during operation and after closure does not differ to a large extend and are thus treated together. The monitoring period taken into account for the cost estimates is 1+30 years and the depreciation period is set to 50 years, ending in 2122. Monitoring will be required after the closure. The expenditure on post-closure monitoring may actually be at the same level as the monitoring during the first 31 years.

The costs of monitoring during the first year of initial filling are considered to correspond to the costs for monitoring during the 30 years of active period. Monitoring costs are considered to largely agree between different facility types (differences in the cost for the required devices are negligible), except the costs for establishing the monitoring wells that might vary with the required depth.

One initial lump sum plus an annual lump sum are assumed and used for the estimate of the most likely monitoring costs for all types of disposal solutions. The initial lump sum includes the establishment of the monitoring wells and the costs for other equipment, whereas the lump sum per year includes personal costs and costs for the analyses.

The overall uncertainty for the monitoring costs is considered by using minimum and maximum percentages of the most likely costs of 75 pct. and 150 pct. respectively.

6.1.7. Cost profile over time and essential assumptions
Cost profiles over time are included in Parliamentary Resolutions B48/2003 (for decommissioning) and B90/2018 (for long-term storage and disposal facilities). An average interest rate of 5 pct. p.a. is calculated on the annual costs of the long-term storage facility as well as the disposal facility. A rate of depreciation is calculated on the basis of a 50 year period for each facility type.

6.2. Financing Schemes, Needs and Estimations

The Danish national programme is financed through the following allocations on the Financial Act. :

- The operating costs of the competent regulatory authority are funded through allocations to the ministries in charge (Health and Defence).
- The operating costs of Danish Decommissioning (license holder) are funded through allocations to the Ministry of Higher Education and Science.
- The project costs of decommissioning are financed through a separate reserve fund of approx. DKK 1 bn.
- The costs of the long-term storage facility and the disposal facility are financed though a separate reserve fund of approx. DKK 2.3 bn. The operating costs of both facilities are covered by the reserve fund. For the long-term storage facility, the reserve fund will finance a 50-year operation period from 2023-2073[30]. For the disposal facility, the reserve fund will finance a 50-year operation period from 2073 to 2122.

6.2.1. Responsibilities, adequacy, availability and security

The responsibility of funding the Danish national programme lies with the Danish Parliament. The adoption of the annual Financial Act, which is a requirement in the Danish constitution, confirms the obligations of Parliament to meet the costs of the national programme and to guarantee the availability of funds at the time when they are needed.

In the event of an unforeseen budget requirement, a motion of approval is prepared by the responsible ministry to be presented to the Financial Committee of the Danish Parliament. The Finance Committee will decide the motion of approval and allow for an additional appropriation. This procedure is typically used for handling the finance of activities where costing is difficult to perform accurately, such as decommissioning projects and other activities related to the management of radioactive waste.

All additional appropriations approved during the financial year are collected in a single appropriations law which is then adopted by Parliament immediately after the end of the financial year.

6.2.2. Re-assessments and validations

Annual re-assessment and validation of required financial resources are performed routinely in coordination with the preparation of the Financial Act. The responsibility lies with the ministries in charge. Hence, the Ministry of Higher Education and Science is responsible for validating required financial resources for Danish Decommissioning's activities and for reporting the results of the validation to the Ministry of Finance for inclusion in the proposal for next year's Financial Act.

[30] The operation period will be shorter as the long-term storage facility will not enter into operation before 2024 at the earliest

7. Programme Implementation

The national policy and its objectives - together with the national legislative, regulatory and organisational framework - constitutes the foundation of the national programme. It is important for all stakeholders involved in the implementation of the national programme to be sufficiently informed and have a common understanding of the national policy, the framework and the objectives.

The programme serves a key purpose in forming a common, basic reference for the respective stakeholders dealing with the practical implementation of radioactive waste management policies. The national programme is a complex of numerous interacting projects and subprojects spanning decades of time over which responsibilities and tasks might be disseminated and redistributed over a number of organisations, entities and companies.

In order to provide for comprehensive implementation, the programme must point out the deliveries and the entity responsible for achieving the deliverable. The programme must also specify who oversees that the responsibilities are lifted; how progress is measured, who measures it and who is responsible for adapting the programme, or its resources, if progress is not according to plan.

An overview of responsibilities, the overarching deliverables of the programme, and means for monitoring progress in the implementation of the programme is provided below.

7.1. Responsibilities

Article 5 of Council Directive 2011/70/EURATOM states that "*Member States shall establish and maintain a national legislative, regulatory and organisational framework ("national framework") for spent fuel and radioactive waste management that allocates responsibility and provides for coordination between relevant competent bodies*."

Circular no. 9654, 2020 on the tasks of the Danish Health Authority and the Danish Agency for Science and Higher Education concerning responsible and safe management of radioactive waste - allocates responsibility and provides for coordination between the relevant institutions. Authority tasks set out in the circular cover all phases of the management of all radioactive waste covered by the Radiation Protection Act - from generation to disposal, including all radioactive waste generated in connection with the operation and decommissioning of nuclear facilities. The main tasks for the relevant authorities and the state institution Danish Decommissioning are briefly outlined below.

7.1.1. Responsibilities of the Danish Health Authority

As part of the implementation and maintenance of the national framework for the management of radioactive waste, the Danish Health Authority shall assist the Ministry of Health by contributing to the preparation, evaluation and updating of a national policy, a national program as well as undertaking the establishment and ongoing updating of a national inventory of radioactive waste. It is also the responsibility of the Danish Health Authority to inform the Ministry of Health as well as relevant ministries and authorities of matters that may necessitate changes of the national framework. The Danish Health Authority shall notify, clarify and report to the Commission on the implementation of the national program (pursuant to Council Directive 2011/70/EURATOM).

The Danish Health Authority must furthermore coordinate and contribute to regularly recurring self-evaluations of the national framework, the regulatory authorities, the national program and its implementation - as well as request and contribute to international peer evaluations with the same scope. The Danish Health Authority is responsible for publishing the results of peer evaluations.

7.1.2. Responsibilities of the Danish Agency for Higher Education and Science

As part of the implementation and maintenance of the national framework for the management of radioactive waste, the Danish Agency for Higher Education and Science assist the Ministry of Higher Education and Science by contributing to the preparation, evaluation and updating of the national program. The agency shall also inform the ministry and relevant stakeholders about matters that may necessitate changes in the Danish regulatory system or national frameworks. Furthermore, the Danish Agency for Science and Higher Education must contribute as relevant to the Danish Health Authority's tasks with regard to notification and reporting, as well as evaluations and peer evaluations.

Concerning the national programme, the Danish Agency for Higher Education and Science must ensure that the necessary information regarding the management of radioactive waste is made available to workers and the public - and that the public has the opportunity to participate effectively in the decision-making process regarding radioactive waste management in accordance with national legislation and international obligations.

Furthermore, the Danish Agency for Higher Education and Science must ensure that qualitative and quantitative performance indicators are established for ongoing, regular assessment of the national programme - and that an assessment is made of the national programme costs and of the programme's current funding schemes.

7.1.3. Danish Decommissioning

Pursuant to Circular no. 64, 2012 on Danish Decommissioning[31], DD is subordinate to the Danish Agency for Science and Higher Education, who sets the basic framework and objectives for DD's operations through the use of performance contracts.

[31] A revised Circular on Danish Decommissioning is in preparation for publication in the first quarter of 2021.

In accordance with the above subordination Danish Decommissioning must effectively assist the Danish Health Authority with inventory and continuous updating of DD's inventory of radioactive waste - as input to the overall inventory. Danish Decommissioning must also maintain and further develop competence, systems and facilities associated with decommissioning and reception of waste as well as to facilitate a long-term solution for the management and disposal of radioactive waste.

Furthermore, Danish Decommissioning is responsible for planning and documenting the management of radioactive waste, taking into account the detailed provisions given by Council Directive 2011/70/EURATOM for instance on existing and planned management methods, technical solutions and interconnectivity between management steps.

7.2. Progress Monitoring

Directive provisions
Council Directive 2011/70/EURATOM sets out provisions for monitoring programme implementation. Pursuant to article 14, Member States shall submit a report on the progress of implementation of the national programme to the Commission by 23 August 2015, and every 3 years thereafter.

In addition, Member States shall periodically, and at least every 10 years, arrange for self-assessments – and invite international peer-review - of their national framework, competent regulatory authority and national programme, with the aim of ensuring that high safety standards are achieved in the safe management of spent fuel and radioactive waste. The outcomes of any peer review shall be reported to the Commission and the other Member States, and will be made available to the public where there is no conflict with security and proprietary information.

These directive-driven mechanisms are taken into account in the overall monitoring of progress on implementation of the national programme described below.

Monitoring progress in implementation of the programme
Progress in implementation of the overall national programme, i.e. the timely and coordinated completion of all projects in all areas of the programme, is not monitored through a single or multiple quantitative measures of (all involved) organisations' progress towards reaching the goals set for the programme. Instead, progress of the programme is evaluated through monitoring of the timely conduct and coordination of deliverables as organised in the programme structure.

The main overview of deliveries across areas over a short, mid and long term perspective in the programme is summarized in the list below:

Short- to mid-term

1. Establish upgraded storage facility, reassessment of radioactive waste inventory, predisposal management and research, development and demonstration activities – taking into account management options for the “special waste”.
2. Review and identification of geologies suitable for disposal down to 500m depth
3. Identify possible disposal concepts incl. feasibility and barrier system studies
4. Designation of most relevant sites for detailed studies based on the outcome of 1-4 and partnership options.

Mid to long term

1. Proposal for one or more specific type(s) of disposal solution(s) to be established
2. Planning Act (for selected option)
3. Construction Act
4. Safety Case and EIA
5. Construction and operation
6. Closure and institutional control

As a consequence of the operational timespan of the programme, the exact timing (and in cases even sequence) of deliverables placed far into the future, is less constrained than deliverables taking effect within the next 5 – 10 years.

The main instrument for monitoring progress in the implementation of the programme will be through reporting to the ministries in annual and tri-annual performance evaluations undertaken by the responsible parties designated in Circular no. 9654, 2020 on the tasks of the Danish Health Authority and the Danish Agency for Higher Education and Research concerning responsible and safe management of radioactive waste. If the reporting includes significant changes in technical or socio-economic conditions, the responsible ministers must be made aware of this. The reporting mechanism is thus an integral part of the implementation process. In the case of fundamental changes in the preconditions, the matter must be discussed politically in committee and in Parliament - after which a political / parliamentary decision can be made.

Monitoring progress for areas

The national programme identifies technical and socio-economic areas as overall constituents of the programme structure. Within each area, several deliverables (objectives to be achieved) have been defined. Deliverables are achieved through completion of projects and sub-projects, conducted by relevant licensees, contractors, authorities etc. Achievement of objectives are not fixed to a specific point in time, but are linked to short-, mid- and long-term perspectives. The deliverable will be completed through conduct of projects and subprojects defined by the party (organisation) responsible for the deliverable. Within each project or subproject, milestones and KPIs will be defined as per routine project management approach by the organisation (or contractor) undertaking the project or subproject.

KPIs applied within each area may provide quantitative information on the progress towards completing projects or subprojects needed for reaching defined objectives (the deliverable). However, KPIs applied at the project level do not necessarily provide meaningful information on the progress toward completing the deliverable, as this to a higher degree may depend on acquired milestones or other qualitative factors such as the timely conduct and coordination within the sum of projects and subproject needed to complete the deliverable.

Performance Contracts
As a specific means to monitor progress of implementation achieved by the national radioactive waste management operator, Danish Decommissioning, which holds overarching responsibilities for the conduct of essential efforts in mainly the technical areas, annual performance contracts are established between Danish Decommissioning, and the Danish Agency for Higher Education and Science under the Ministry of Higher Education and Science.

In the performance contract, Danish Decommissioning states its mission, vision and strategic priorities, which are translated into result targets to be executed within one year of operation. In example, the performance contract for 2021 states the following strategic priorities:

- Safe and Efficient Decommissioning
- Safe Mangement of Radioactive Waste
- Openness and Dialogue
- An Attractive and Competent Workplace

The strategic priorities are translated into the following result target areas for 2021:

- Decommissioning (4 targets)
- New Upgraded Storage Facility (3 targets)
- Long Term Solution for Radioactive Waste Management (4 targets)
- Operative Functions and Institutional Waste Management (2 targets)
- Technical Support Functions (5 targets)
- Administrative Support Functions (2 targets)

Each target is described according to 1) Outcome and 2) Activity to Achieve Outcome.

The Performance Contract is supplemented by a contract specifying the personal performance targets of the CEO of Danish Decommissioning. Both contracts are reviewed and evaluated by the end of the calendar year. By conducting a full evaluation of the contracts, the Danish Agency for Higher Education and Science is in a position to closely monitor and adjust the priorities and performance targets of Danish Decommissioning. The Performance Contract is published on the website of Danish Decommissioning (www.dekom.dk) whereas the personal contract of the CEO is confidential.

Appendix 1

Types of national regulations and resolutions

The Danish legislative hierarchy comprise:

- Acts; establishing authorities, their obligations and their authoritative framework of action, as well as prohibitions. Acts are typically proposed (bills) by ministries, considered and eventually passed by Parliament.
- Consolidation Acts; administrative summaries of original acts and their subsequent amendments. The adoption of a consolidation act is done by the relevant minister.
- Executive Orders; administrative regulations based on one or more acts (or consolidation acts) and issued either by a ministry or an appointed authority. An executive order may contain rules that are binding on both citizens and authorities.
- Circulars; administrative regulations issued by e.g. a ministerial department, typically containing provisions aimed at hierarchically lower-ranking institutions such as authorities and agencies. Circulars, unlike executive orders, cannot directly oblige citizens or undertakings.

In addition, the Parliament can adopt Parliamentary Resolutions:

- Parliamentary Resolutions; policy decisions adopted by Parliament. The Government is not constitutionally obliged to follow an adopted parliamentary resolution, but risks a “no confidence”-vote and if so, election of a new Folketing and Government.

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