2 Long-Term Radioactive Waste Management in the Netherlands: Seeking Guidance for Decision-Making

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2.1 Introduction

The Netherlands currently stores its radioactive waste above ground at the Central Organization for Radioactive Waste (COVRA). With regard to the long-term management of radioactive waste and spent fuel, the Netherlands pursues a 'dual strategy'. First, there is a national route in which the government envisions a geological disposal facility (GDF) for a part of its radioactive waste and spent fuel to be operational by 2130 (Ministry of I&E, 2016). Nevertheless, the option is left open to deviate from this timeframe, as well as from the currently preferred long-term disposal method (geological disposal), if there is reason to do so. Second, the government pursues an international route with other European Union (EU) Member States for the long-term management of radioactive waste (Ministry of I&E, 2016). Although an approximate timeline has been developed, the concrete decision-making process that should lead to a solution, either nationally or internationally, has not yet been established.

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The Netherlands is a medium-sized country with regard to radioactive waste, characterized by a diverse nuclear technology portfolio (with four operational nuclear facilities for energy, research, uranium enrichment and the production of medical isotopes). Approximately 1,300 companies hold a license to work with radioactive materials, of which two-thirds produce radioactive waste (Ministry of I&E, 2016). In 2020, the central national facility of COVRA in Borsele contained a total of 35,411.1 m^3 radioactive waste. 110.1 m^3 of this was high-level radioactive waste (HLW), while 34,168 m^3 of the waste stored was low-level and intermediate-level radioactive waste (LILW). Some 70% of the HLW brought to COVRA annually originates from the production of nuclear energy, and 30% comes from the production of medical isotopes and from the research reactors in Delft and Petten. The LILW stems from various sources, such as nuclear reactors, research facilities, hospitals, gas- and oil-drilling, discarded smoke detectors, and the enrichment of uranium by the Netherlands branch of Urenco (COVRA, 2020a).[1] Because of the relatively small volumes of radioactive waste produced in the Netherlands, and the relative high initial costs of geological disposal, the Dutch government wants to place LILW that is still active at the time of disposal in the same location as the HLW (Ministry of I&M, 2016). This is in contrast to other countries, such as Belgium, France and the UK, where ('short-lived') LILW is to be placed in a surface or near-surface disposal facility (cf. Schröder, 2012).

At present, there is no detailed step-by-step approach to decision-making on the long-term management of radioactive waste in the Netherlands. Therefore, following the National Program Radioactive Waste (Ministry of I&E, 2016), in 2019, the State Secretary for Infrastructure and Water Management commissioned the Rathenau Instituut to provide advice in 2024 on the decision-making process regarding the long-term management of radioactive waste.[2] The Rathenau

[1] The classification system currently used in the Netherlands resembles the IAEA guideline of 2009 (IAEA Safety Standard, 2009), but consists of four categories instead of six: 'high-level radioactive waste' (HLW), 'low-and medium-level radioactive waste' (LILW), 'short-lived waste' (with a half-time of less than 100 days) and 'exempt waste' (COVRA, 2014). A subcategory of LILW consists of waste produced from the use of naturally occurring radioactive material (NORM). NORM waste with an activity concentration of up to ten times the exemption threshold, are disposed of as very low-level waste at special licensed dumpsites (Ministry of I&E, 2016, p. 16). In this chapter, we only focus on the long-term management of the waste stored at COVRA.

[2] The Rathenau Instituut is an independent technology assessment organization. It has been involved in research and debate about the impact of science, innovation, and technology on society for 35 years.

Instituut aims to fulfill this task by organising research and dialogue between citizens, experts and stakeholders. The authors of this chapter are involved in this advisory process, of which this book and chapter are a part.

This chapter investigates various important challenges for the decision-making process regarding the long-term management of radioactive waste in the Netherlands. To this end, we use the conceptual model of a multi-level governance ecosystem (Kool et al., 2017), as explained in the introductory chapter, which consists of four domains and their interactions: 'politics and administration', 'science and technology', 'laws and regulations', and 'civil society'. We first describe the historical development of the governance ecosystem in the Netherlands, based on a reading of parliamentary documents, publications from the national waste management organisation (COVRA), governmental organisations, NGOs, news items, previous reviews of the national nuclear sector, as well as literature on the governance of radioactive waste. Based on that overview, we reflect on the developments within the separate domains and identify current challenges for decision-making. We end by drawing several conclusions.

2.2 History of Radioactive Waste Management and Policy in the Netherlands

This section describes how the Netherlands managed radioactive waste from 1945 to 2016, and how decision-making took shape. This timeframe spans the period between the building-up of the nuclear sector to the first National Program for the management of radioactive waste. Since the management of radioactive waste is closely linked to its applications, we also take developments in the field of nuclear technologies into account. We show that over the years different waste management methods have been suggested, discussed, researched, used, regulated, banned, and/or abandoned. For each of these methods, specific decision-making processes took place, in terms of technical viability, and social and political-administrative desirability and legal admissibility.

2.2.1 Development of the Nuclear Sector and Laws and Regulations for Nuclear Safety and Radiation Protection in the Netherlands

After World War II, with the support of the United States, the Dutch government teamed up with scientists to explore the peaceful potential of nuclear technology.

To this end, the government set up a knowledge and research infrastructure, developed industrial policy, and provided information about nuclear technology to the general public (Ministerie van Economische Zaken, 1957). The Netherlands also became a shareholder in Eurochemic, an international company founded in 1957 within the framework of the Organization for European Economic Cooperation (OEEC). Its purpose was to build a factory for reprocessing spent fuel, situated in Belgium. Dutch nuclear reactors came online for research and education in Petten (1960 and 1961), Delft (1963), Wageningen (1963), and Eindhoven (1969). Nuclear power plants (NPP) became operational in Dodewaard (1968) and Borssele (1973). There was relatively little attention to radioactive waste management (RWM) during this build-up phase, which also held true for waste management in most other sectors at that time (cf. IAEA, 2002). Over the years, there was a gradual increase in attention to radioactive waste, driven by an international scientific discussion on how such waste should be handled.

In the 1950s and 1960s, new organisations were set up to promote the safe use of nuclear technology, such as the International Atomic Energy Agency (IAEA) in 1957, the European Nuclear Energy Agency (ENEA, later NEA) in 1958, and the European Atomic Energy Community (Euratom) in 1958. The Dutch government implemented legislation and regulations on nuclear safety and radiation protection due to the expected increase in the use of radioactive substances in medical, biological, industrial and agricultural fields (Radioactieve Stoffenbesluit, 1958, p. 7). On the basis of agreements within the Euratom Treaty, the Ionizing Radiation Decree (Radioactieve Stoffenbesluit, 1958) provided guidelines with regard to safety. In addition, the government used existing legislation to create the preconditions for protection against ionizing radiation for employees and the general public. In 1963 the Nuclear Energy Act was passed, that governed nuclear activities and provided regulations for nuclear safety and radiation protection (Kernenergiewet 1963). This law, which still applies, is a so-called framework law, with associated Decrees and Ordinances providing more detailed legislation.

During the first two decades of the nuclear program in the Netherlands, there was no explicit radioactive waste policy, just as there was no regular waste policy. However, a practice of managing radioactive waste did emerge (Berkers et al., 2023). In 1963, the Minister of Social Affairs and Health established a special designated service to collect LILW waste. This radioactive waste was subsequently stored above ground in Petten, near the Reactor Center Netherlands (RCN). Part of this waste was disposed in the deep sea. This latter practice was supervised by ENEA after 1965. Between 1966 and 1974, spent nuclear fuel was reprocessed at Eurochemic in Belgium, where—according to contract—the leftover HLW remained. After Eurochemic shut down in 1974, new agreements

were made for the reprocessing of spent fuel with the United States, United Kingdom and France. The remaining Dutch HLW would eventually be sent back from the UK and France to the Netherlands. At the same time, social resistance to the dumping of radioactive and other high-toxic waste into the deep sea grew, both within and outside the Netherlands, and an international ban on the dumping of HLW into the sea came into effect in 1972. An international moratorium on dumping LILW was issued in 1983, followed by a complete ban in 1993.

2.2.2 Realizing an Above-Ground Interim Storage Facility for Radioactive Waste

RWM became a topic in the Dutch societal arena in the 1970s, as exemplified by the societal resistance to deep sea dumping. RWM also became a central issue in the nuclear energy debate as the anti-nuclear movement arose. Furthermore, the government at the time indicated that expanding nuclear energy was only possible after an 'acceptable solution' was found for radioactive waste (Ministerie van Economische Zaken, 1974). In line with international scientific debates, the Scientific Council for Nuclear Energy, and the Reactor Center of the Netherlands, among others, advised to examine the possibilities of disposing radioactive waste in deep underground salt domes (cf. WRK, 1972). In 1976, the government wanted to investigate the technological possibilities of disposing HLW in salt formations in the northeastern part of the Netherlands. Regional and local resistance by citizens, societal organisations, companies and politicians eventually obstructed the proposed in situ test drilling (Berkers et al., 2023).

In 1981, the government initiated a Broad Social Discussion (BMD) on energy policy in response to the political and social impasse that had arisen. Within the BMD nuclear energy and radioactive waste were important topics. In 1984, the BMD Steering Committee advised to keep existing nuclear power stations open, but concluded that expansion of nuclear energy was undesirable.[3] Despite this, the government opted for the construction of two new NPPs, leaving many nuclear-critical participants in the BMD indignant. Political support for nuclear energy disappeared after the Chernobyl accident in April 1986, and the two pro-

[3] This Steering Committee consisted of nine experts from political and scientific circles, and was chaired by Mauk de Brauw, a socialist politician who had been minister of academic education and research, and previously worked for various companies including Unilever.

posed NPPs were never built. During the same period, the importance of nuclear medicine grew considerably. In the Netherlands, the High Flux Reactor (HFR) at Petten began to play a central role in the (world-wide) production of medical isotopes (Vijftig jaar HFR, 2011).

These societal and political developments impacted scientific research as well as the policy process (Schröder, 2012). The Integral National Research Program Nuclear Waste (ILONA) started in 1981. ILONA consisted of various committees that examined different possibilities for the disposal of HLW: storage on land, just above or below the earth's surface, interim-storage of spent fuel elements and nuclear fission waste, disposal in salt domes in the North Sea, and disposal in geological layers beneath the deep seas (Ministerie van VROM, 1984). The research on North Sea salt domes and deep sea geological disposal was rather quickly abandoned due to higher than expected costs (Berkers et al., 2023). In 1981, the Committee Reconsidering Disposal of Radioactive Waste (Commissie Heroverweging Verwijdering Radioactief Afval, HVRA) was installed to look for alternatives for the deep sea disposal of LILW (Ministerie van VROM, 1984, p. 12). HVRA concluded in March 1983 that it had a preference for disposing LILW in salt layers, e.g. by means of deep salt cavities (Berkers et al., 2023).

The first RWM policy was presented in 1984 by the Minister of Housing, Spatial Planning and the Environment (VROM). It included two goals in the field of radiation protection. First, to comply with the ALARA (As Low As Reasonably Achievable) principle, which had been recommended by the International Commission on Radiological Protection (ICRP) in 1973 and endorsed by Euratom in 1980. This had to be done by isolating, managing and controlling the waste (in Dutch the so-called IBC-criteria). Second, the sum of the received and expected doses for humans should not exceed the established dose limits. The government also decided to set up an above-ground interim storage facility for LILW and HLW. This should be managed by COVRA, for a period of 'several decades', which was later explained during parliamentary debates and related policy documents as at least 100 years (Ministry of I&E, 2016). This temporal policy provided time to further study options for a final GDF and to explore the possibility of an international disposal facility. A designated committee under the aegis of liberal politician W.J. Geertsema was tasked with finding a suitable and acceptable location for the intended facility. This eventually led to an above-ground radioactive waste storage facility in Borsele, near the NPP. Local residents and the anti-nuclear energy movement participated in this decision-making process. By August 1989, COVRA had obtained all necessary permits and was able to start construction of the storage facility.

2.2.3 Deep Geological Disposal: Elaboration of Policy and Research

In subsequent decades, the government elaborated on its 1984 radioactive waste policy through parliamentary debates, research and public consultation. This included the formulation of an environmental policy framework, informed by a public consultation on the acceptability of geological disposal of (radioactive and highly-toxic) waste. This led to new modified principles for RWM: in line with the IBC-criteria, reversibility of the decision-making process and retrievability of the waste became requirements (Tweede Kamer, 1993). With this in mind, the national scientific Committee on Storage of Radioactive Waste (CORA) was asked by ILONA in 1996 to investigate the feasibility of retrievable disposal of radioactive waste both in salt domes and Boom Clay. In addition to technical aspects, one of its subcommittees focused on ethical and social aspects of long-term RWM in a scoping study amongst environmental organisations (CORA, 2001; Selling, 2002). This was the first time a social scientific angle was included in a national research programme on RWM in the Netherlands.

The work of international organisations influenced Dutch RWM policy and research. This concerned, for example, international agreements in the IAEA-framework, international radiation guidelines and standards by the International Commission on Radiological Protection (ICRP) (via Euratom), and the work of the Nuclear Energy Agency (NEA). The NEA developed the concept of a safety case, which 'comprises the findings of a safety assessment and a statement of confidence in these findings' (OECD, 1999, p. 22). The safety case methodology was applied in the national Research Program for the Final Storage of Radioactive Waste (OPERA), which ran from 2011 to 2016. This program was organised by COVRA, and looked in particular into the possibilities of a geological disposal facility in Boom Clay. In 2004, NEA also argued for a stepwise approach to decision-making, which was in line with the Dutch principle of reversibility. Furthermore, NEA stated that it is important that 'the public, and especially the most affected local public, are meaningfully involved in the planning process' (OECD, 2004, p. 7). With regard to the legal domain, the Aarhus Convention came into effect in 2001, and grants EU citizens the right to access to information, public participation in decision-making, and access to justice in environmental matters (UN, 1998).

Institutional arrangements also changed during this period, with several changes in the division of ministerial tasks and responsibilities in the field of nuclear energy, nuclear safety and radiation protection. For example, since 2010

the Ministry of Economic Affairs was responsible for nuclear safety and radiation protection, nuclear energy, the Nuclear Energy Act and the management of the associated organisational units. The Minister of Social Affairs and Employment (SZW) was responsible for the protection of employees, and the Minister of Health, Welfare and Sport (VWS) was responsible for protecting patients against the risks of ionizing radiation (ABDTOPConsult, 2019). Influenced by the House of Representatives and international guidelines from the IAEA, it was decided in 2015 to set up a new independent Authority for Nuclear Safety and Radiation protection under the Ministry of Infrastructure and the Environment (I&E): the ANVS. The new authority could not fall under the Ministry of Economic Affairs, which was responsible for (nuclear) energy policy (Wijzigingswet kernernergiewet, 2016). In 2019, a legal evaluation of the ANVS led to the transfer of policy responsibility for the management of radioactive waste to the Ministry of Infrastructure and Water Management (before I&E).

The EU also had an influence on the decision-making process regarding the disposal and management of radioactive waste in the Netherlands. In accordance with the 2011/70/Euratom directive, every EU Member State became obliged to draw up a National Program (European Council, 2011). In preparation for the Dutch National Program, four studies were carried out: 1) an inventory of the current and future volume of radioactive waste by COVRA; 2) an initial study into options for the long-term management of radioactive waste by engineering consultancy ARCADIS; 3) a study on public participation by the Rathenau Instituut; and 4) a study of the state of affairs concerning international research into disposal by the Nuclear Research & Consultancy Group (NRG).

Building on earlier policies, the National Program from 2016 listed the following four policy principles: 1) minimization of the generation of radioactive waste; 2) safe management of radioactive waste; 3) no unreasonable burdens on the shoulders of later generations; 4) the producers of radioactive waste are responsible for the costs of its management (Ministry of I&E, 2016). In addition, the National Program underlined the importance of public participation and the earlier mentioned dual strategy. Because the Netherlands has a relatively small volume of radioactive waste, a multinational repository was considered logical "in terms of quality, safety, knowledge sharing, care and costs" by the consultancy group of OPERA (Adviesgroep OPERA, 2017, p. 50).[4] International

[4] The consultancy group consisted of seven members from different backgrounds, such as regional authorities, drinking water boards and universities.

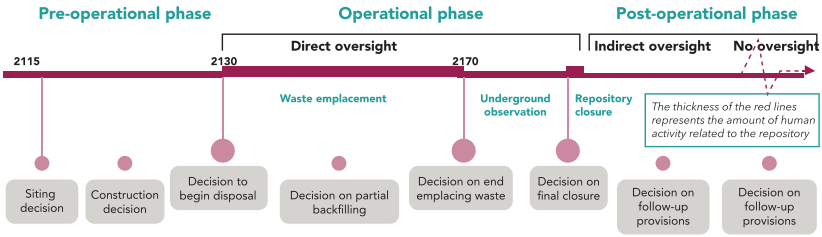

Fig. 2.1 Suggested timeline in the National Program of important decision-making moments for a GDF. (Source: OPERA, figure from OECD/NEA adapted to the Dutch situation)

collaboration is sought for this route within the European Repository Development Organization (ERDO), which has been based at COVRA since 2021. Several European Member States, including the Netherlands, work within this international association on multinational radioactive waste solutions (COVRA, 2021).

The National Program opted for interim above-ground storage for at least 100 years, followed by geological disposal. It also suggested a timeline: a political decision on a final repository will be made around 2100, and the GDF is to be operational around 2130 (see Fig. 2.1). It is however possible to deviate from this, both in terms of the timeframe and disposal method, for example due to technological developments or international cooperation. The government legitimised this policy by stating that "the relatively long period of above ground storage will provide time to learn from experiences in other countries, to carry out research and accumulate knowledge" (Ministry of I&E, 2016, pp. 4–5). This should ensure that no unreasonable burden is placed on the shoulders of future generations.

The National Program also announced the construction of a consultation group (Klankbordgroep) that would be tasked to focus on issues including:

- public participation ('identifying specific forms of participation');
- siting of radioactive waste disposal facilities ('potential suitable search areas for the disposal of radioactive waste that can be reserved, and identifying the necessary policy harmonization, given other future functions of the (deep) underground environment at those sites');
- knowledge infrastructure ('options for maintaining the necessary knowledge infrastructure in the Netherlands for the management of radioactive waste'), and;

- practical implementation of the principle of retrievability ('defining the criteria for determining the period of retrievability of radioactive waste from disposal to allow a decision on a period of retrievability supported by society'). (Ministry of I&E, 2016, p. 6)

The Ministry of I&W asked Van Soest to explore how such a consultation group process could be organisationally embedded. Van Soest concluded that the mission of such a group could be "to think through a possible participatory decision-making process aimed at a social agreement about the disposal of radioactive waste and spent fuel, and to advise relevant parties on this" (Van Soest, 2018, p. 8). As a result of this preliminary investigation, it was decided to task the Rathenau Instituut with issuing advice in 2024 on the decision-making process regarding the long-term management of radioactive waste.

2.3 Current Challenges

The long-term interim above-ground storage at COVRA provides time to work on a final solution for the long-term management of radioactive waste. While the National Program provides a tentative timeline, the step-by-step process of decision-making needs further elaboration. To better understand the challenges that need to be addressed, this section reflects on historic and current development of the four domains of the governance-ecosystem: 1) laws and regulation, 2) policy and administration, 3) science and technology, and 4) civil society. Because each domain depends on the others for their functioning, we consider their mutual interactions. Moreover, since various levels of government play a role in dealing with radioactive waste, we also consider the multi-level character of the domains.

2.3.1 Laws and Regulations

In the Netherlands, legislation and regulations regarding the management of radioactive waste are part of the legal framework for radiation protection and nuclear safety. This is covered by the Nuclear Energy Act of 1963 (Kernenergiewet 1963). This Act, and its associated decrees and ordinances, have been continuously adapted to guidelines provided by international organisations such as IAEA, Euratom, and ICRP. Various political and social developments have had an influence on international legislation and regulations. This for example has led to international bans on the dumping of radioactive waste into the deep sea, and

to a European Directive for the responsible and safe management of spent fuel and radioactive waste—which pays attention to public information provisioning and public participation. Moreover, the latter is in line with more general (international) regulations such as those drawn up under the Aarhus Convention, and obligations for public participation as part of licensing (UN 1998). A study of the current legal framework for the long-term management of radioactive waste concludes that the Dutch framework complies with all international and European rules for RWM, and that most of the recommendations of the IAEA have been followed (Akerboom, 2023).[5]

2.3.2 Policy and Administration

Since the advent of nuclear technology in the Netherlands, the domain of politics and administration gradually started to pay attention to RWM. To enable the safe use of nuclear technology, the nuclear sector was institutionalized (both internationally and nationally), which led to guidelines for the management of radioactive materials, including radioactive waste. In the 1970s, RWM became part of the societal and political debate on nuclear energy. That, combined with international scientific debates on radiation protection standards, led the government to set up various research programmes and organise the Broad Societal Discussion (BMD) on energy policy. Both inputs were used to formulate the 1984 radioactive waste policy plan. This policy opted for the long-term interim above-ground storage of radioactive waste. To achieve this, COVRA had been established in 1982, and a GDF was foreseen as a long-term solution via either a national or an international route. The National Program reaffirmed this policy in 2016, and offered a timeline according to which the political decision on a final repository will be taken around 2100, and a GDF will be operational around 2130 (see Fig. 2.2). Since EU regulations require that National Programs need to be updated every ten years, a new one is scheduled for 2026.

Dutch RWM policy has been both hailed and criticized. First, the organisation of centralised long-term interim above-ground storage of radioactive waste has been deemed as ‘good governance’ by member states of the Joint Convention on the Safety of Spent Fuel, and on the Safety of Radioactive Waste Management, because the packaging and storage facilities are also designed with a term of 100

[5] This study has been conducted as part of the current assignment of the Rathenau Instituut.

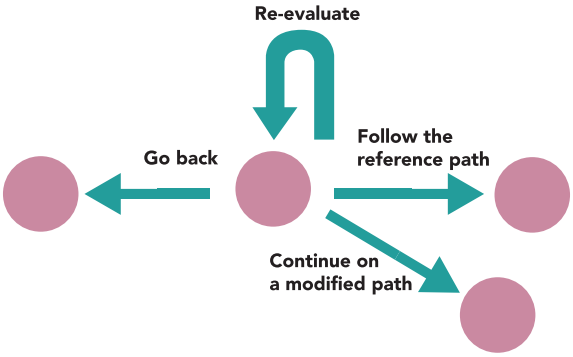

Fig. 2.2 Reversibility of decisions. (Source: National Program, adapted from OECD/NEA)

to 300 years in mind, which facilitates a high level of safety (Ministry of I&W, 2020). In line with this, the IAEA (2009) considered the incorporation of passive safety features in the design of the packaging and facilities as a 'good practice', because it makes the safety of the interim-storage less dependent on maintenance, and the packaged materials can be monitored more easily. Second, the IAEA concluded that COVRA communicates well with the public, for example through art and by organising open days, which has increased the confidence of the public regarding the activities of COVRA (IAEA, 2009).

There is also criticism, for example on the intention not to realize a GDF until 2130. According to LAKA, a Dutch documentation and research center rooted in the anti-nuclear energy movement, the long duration of this more than 100-year period can lead to a political "wait-and-see" situation in the present (LAKA, 2015). A similar point is put forward by the advisory board of OPERA.[6] They supported the century-long horizon, but remarked that this time period should be used effectively, as it could lead to a lack of urgency among contemporary politicians and policymakers. They advised to start with public participation and scientific research as soon as possible (Adviesgroep OPERA, 2017). However, the study by the Rathenau Instituut that was carried out in preparation for the

[6]The OPERA advisory group was asked to advice on the quality of the research and on its social relevance. In addition, they had an advisory role on the communication about the program and the results.

National Program, showed that the absence of actual decisions negatively impacts the sense of urgency amongst the public, making public participation a complex challenge (De Vries et al., 2015).

Other organisations also emphasise that the period up to 2100 should be used meaningfully. The Netherlands Commission for Environmental Assessment (NCEA) advised the designation of a number of potentially suitable search areas for possible disposal of radioactive waste, to prevent an outcome that by the year 2100 the most suitable sites for geological disposal of radioactive waste would already be occupied (Commissie m.e.r., 2015).[7] Reserving potential search areas implies an implicit choice for a disposal method and a location, for which provisional selection criteria must be determined. However, it is uncertain whether the subsurface will actually become fully occupied, in view of the current strong social resistance to and distrust of various existing and potential developments in the Dutch subsurface, which ranges from natural and shale gas extraction (Waes et al., 2014) to CO_2 storage and geothermal energy (Smink et al., 2017). Therefore, it should be made clear whether, and if so at what moment in time, search locations for a potential GDF *have* to be reserved. This challenge has been included as a point of attention in the National Program (Ministry of I&E, 2016).

Other actors have also made suggestions about how the long-term interim period should be used. In 2019, the advisory board of the ANVS suggested that the ANVS should open the discussion about bringing forward decision-making by the government regarding the type and location of a final GDF (Raad van Advies, ANVS, 2020).[8] This would allow for more time to study and evaluate the host rock, and realize the selected type of disposal in 2130. Based on experiences from other countries, this might take a long time. A study commissioned by the Ministry of I&W recently concluded that stakeholders are in need of a more detailed step-by-step plan that identifies moments for public consultation and decision-making (Berenschot, 2022). To date, there is no such plan (Ministry of I&E, 2016). The European Commission (EC) even questioned in 2017 whether the government had in fact taken reasonable and concrete steps to ensure that future generations will not have to carry the burden of radioactive waste produced in the

[7] The Netherlands Commission for Environmental Assessment (NCEA) advises governments on the quality of environmental information in environmental assessment reports. The NCEA does not get involved in decision-making or political considerations.

[8] The advisory board of the ANVS consists of independent experts from the Netherlands and abroad, its task is to provide the ANVS with solicited and unsolicited advice on matters related to the tasks of the ANVS.

past and present, as required by the Euratom guidelines (Tweede Kamer, 2017). In response to this question, the Minister of I&M referred to the reasons for the current policy as stated in the National Program, and to the government plan to start a consultation group. As noted, the latter gave rise to the current assignment to the Rathenau Instituut.

Although the policy intention to switch to geological disposal following a period of above-ground storage has not changed since 1984, two additional requirements have been set for the long-term management of radioactive waste. The principle of retrievability has been given a somewhat narrower interpretation in the National Program than in the 1993 Parliamentary paper, by stating that it means "that the possibility for retrieving waste (packages) must be included in the design of a facility" (Ministry of I&E, 2016, p. 26). The optimum period of retrievability is to be decided in consultation with society. In addition, as far as practically desirable, the decision-making process must be reversible. This is associated with the step-by-step approach to licensing (Ministry of I&E, 2016) and is explained as follows: "before each step is taken, consideration will have to be given to whether the step should be taken, or whether a step back should be taken in the process" (see Fig. 2.2). Although this principle offers the opportunity for flexible decision-making, according to the Committee's environmental impact assessment, the concept version of the National Program did not provide instruments or mechanisms to reassess risks and adapt to unexpected developments (Commissie m.e.r., 2015). It remains unclear to what extent decisions should be reversible—with a view to 'manageability'—and how this should be assessed.

Another important development over the last two decades is the redistribution of ministerial tasks and responsibilities. Since the 1950s, responsibility for both nuclear energy and nuclear safety in the Netherlands has rested most of the time with the Ministry of Economic Affairs. In 1994, the IAEA Convention on Nuclear Safety stipulated that each Member State had to ensure a separation between organisations in the fields of nuclear safety and nuclear energy. Currently there is a clear division between the responsibilities for energy policy that lie with the Ministry of Economic Affairs, and on the responsibilities for nuclear safety and radiation protection that lie with the Ministry of I&W. The ANVS, established in 2015, was given both policymaking and supervision responsibilities. In 2020, the responsibility for policymaking was transferred from the ANVS to the Ministry of I&W. This creates a better distinction between the duties of the Ministry of I&W, and ANVS as a supervisor and licensing authority (ABDTopconsult, 2019).

In recent years, the nuclear energy discussion has resurfaced, partially because of the climate crisis. In the wake of this discussion, radioactive waste also returned to the political and social agenda. In its coalition agreement, the current

government intends to keep the nuclear power plant in Borssele open longer, to build two new NPPs, and to provide for the safe disposal of nuclear waste (Kabinetsformatie, 2021). What this will mean for the decision-making process regarding the long-term management of radioactive waste remains to be seen.

2.3.3 Science and Technology

The domain of science and technology continues to play an important role in the development of standards for radiation protection and nuclear safety. The same holds for the investigation of the viability and safety of technical options for (long-term) RWM. It thereby influences the development of legislation, regulations, and policy. Below, we describe how despite increased awareness of the importance of interdisciplinary and transdisciplinary knowledge, an integral, participatory and sociotechnical knowledge agenda is still missing in the Netherlands, and it is unclear where the institutional responsibility for such an agenda lies. Moreover, we highlight that the vitality of the science and technology domain would benefit from a long-term vision on knowledge development.

Until the 1990s, Dutch RWM research primarily focused on technical aspects, such as the technical feasibility of geological disposal in salt domes. From CORA (which ran from 1996 to 2001) onwards, ethical and social aspects of the long-term management of radioactive waste, and the role of public participation in decision-making, have received attention. Within ILONA (the research program which ran between 1981 and 1993), it was argued that social scientific research should be limited to an inventory of the processes that play a role in decision-making (Tweede Kamer, 2002). OPERA, the subsequent national research program (which ran from 2011 to 2018), set up the previously mentioned OPERA advisory group. The group dealt with the "wider societal issues of disposal, including stakeholder engagement and conditions for an inclusive process for long-term decision-making on disposal" (Verhoef et al., 2017, p. 8). The advisory group stated that this requires a participatory process and the recognition of emotions and values, which can be used to shape and direct technological development; so-called "value sensitive design" (cf. Correljé et al., 2015). In 2015, the Rathenau Instituut concluded that RWM transcends various academic disciplines (technical, geological, ethical, social, psychological, economic), and that it is therefore important "to retain sight of the issue's multidisciplinary character and the consequent need for interdisciplinary cooperation" (De Vries et al., 2015, p. 19). Despite intentions to set up a broader research program, the current

long-term program at COVRA focuses primarily on technical aspects. A more integrated sociotechnical research agenda is thus still lacking.

Moreover, it is unclear where the institutional responsibility for setting up such an integral research agenda lies. According to the IAEA, the government should be responsible for ensuring that the necessary knowledge and expertise is maintained (IAEA, 2000). As seen above, since the beginning of the 1980s, the government and the nuclear sector have developed various research programmes in collaboration with a specially designated scientific committee. However, currently the government's involvement in research on the final disposal of radioactive waste is somewhat limited. After the CORA research program ended in 2001, COVRA started to play a key role in coordinating research (Berkers et al., 2023).[9] And for the first time, the current research program is not financially (co-)supported by the government, but solely financed by COVRA (COVRA, 2020b). Part of the money that COVRA receives from the producers of radioactive waste is used for this purpose.[10]

According to the consultancy firm Berenschot (2022), this and previous research programmes have been appreciated by companies and NGOs, however, they also experience a lack of insight into the current steps of knowledge development regarding disposal: "[even though] the report of the research programs are public […] it is not clear what will happen with these insights and what the next steps are. Linked to this, an overview of the lessons until now, and what we still want/need to know before a safe geological disposal facility can be realized is lacking"[11] (Berenschot, 2022, p. 19). This raises the question to what extent it is up to COVRA to provide insights into these aspects, or whether this should be a responsibility of the government, or a combination of both. In addition, stakeholders have also indicated that the lack of insight into what still needs to be investigated to realize a GDF is related to the absence of a more detailed step-by-step decision-making process (Berenschot, 2022). As mentioned before, the lack of this step-by-step plan is another challenge for the government, and part of the present assignment of the Rathenau Instituut.

[9] Although COVRA is fully owned by the Dutch state, it is an independent administrative body (in Dutch: Onafhankelijk Bestuursorgaan) that performs government tasks, but does not fall directly under the authority of a ministry.

[10] This is in line with the polluter pays principle. This principle assures that organisations which deliver their radioactive waste to COVRA pay for all costs related its management, including research (COVRA, 2020b).

[11] Translation from Dutch by authors.

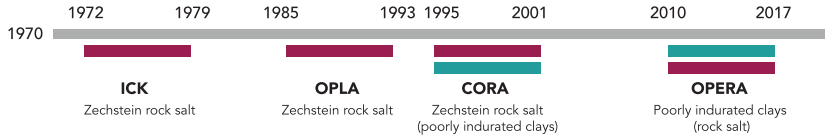

Fig. 2.3 Overview of Dutch research programs (COVRA, 2020b)

The NEA recommended that the public should be involved in the development and implementation of a safety case (OECD, 2000). The Rathenau Instituut proposed that a participatory knowledge agenda is an essential feature of knowledge assurance for decision-making on the long-term management of radioactive waste. Such an agenda should be based on "information sources originating from […] citizens, scientists in various disciplines, stakeholders and (lower tiers of) government" (De Vries et al., 2015, p. 46).[12] A transdisciplinary mode of knowledge production is seen as important in science in general (cf. Gibbons & Nowotny 2001; Nowotny, 2003) and in RWM in particular (Brunnengräber, 2019), because it may contribute to more socially robust knowledge. There has been some level of involvement in Dutch research programmes, by means of informing the public and parliament of plans and findings, and by collaborations between science, industry and policy. However, the general public has so far been absent in the design and execution of research programmes. Involving civil society actors, such as citizens and civil society organisations, remains a challenge in the Netherlands, since those actors may lack the will or resources to participate (De Vries et al., 2015). These issues should be addressed in order to develop a participatory knowledge agenda.

The permanence and vitality of the science and technology domain remains a point of attention. Successive research programmes often had gaps between them ranging up to ten years (see Fig. 2.3). In some cases, this implied that "earlier collected knowledge had to be recovered and that the research infrastructure on the geological disposal of radioactive waste had been diminished and weakened over time" (COVRA, 2020b, p. 12). To prevent this from happening in the future, COVRA's most recent research programme has a long-term scope.

From the point of view of institutional independence, checks and balances, and spreading knowledge, as well as COVRA, the Ministry of I&W, ANVS and

[12] While preparing the national programme, ANVS asked the Rathenau Instituut to formulate a vision on public participation in decision-making about long-term radioactive waste management, to serve as a supporting study for the national programme.

other relevant stakeholders must also continue to have access to sufficient and (independent) knowledge and expertise to continue to perform their institutional duties (cf. Raad van Advies ANVS, 2020). The Ministry of I&W is currently exploring how the knowledge landscape of nuclear technology and radiation can be strengthened, including in the long term (cf. Van de Zande et al., 2020).

2.3.4 Civil Society

Over the last few decades, the societal domain has been involved in decision-making on the long-term management of radioactive waste in several ways. In some cases, involvement was initiated by the government, and in others by civil society actors themselves. We show here that this had various outcomes, and took multiple forms: from protest and resistance to informing and consulting. Over the years, awareness of the importance of public involvement in radioactive waste decision-making has increased. It even became legally required by international and national guidelines, treaties and laws. Part of the assignment to the Rathenau Instituut is to develop an advice on a (possibly participatory) decision-making process for the final disposal of radioactive waste on behalf of the Ministry of I&W. This has been lacking until now, partly due to the absence of concrete decision-making steps, which influences willingness to participate.

Civil society has influenced both policy and research. In the 1950s, companies worked closely with scientific institutions to erect a nuclear industry in the Netherlands. In the early 1970s, governmental policy to expand the nuclear sector was criticized by an emerging anti-nuclear energy movement. Dealing with radioactive waste became a central issue in the nuclear energy debate after the government indicated that expanding nuclear energy was only possible if an 'acceptable solution' had been found for radioactive waste. At the same time, the existing practice of disposing radioactive waste in the deep sea was also met with increasing public protest, resulting in a ban for first HLW (1975), and subsequently LILW (temporary moratorium in 1983, legal ban in 1993). The announcement of in situ test drillings in salt layers in the northeastern part of the Netherlands to find potentially suitable places for a GDF, led to regional political-administrative and social resistance among both proponents and opponents of nuclear energy. To this day, conducting research in the subsurface for the geological disposal of radioactive waste remains a sensitive issue (De Vries et al., 2015).

The government has also consulted the public on policy development at various times—often under pressure from parliament, local and regional authorities, and society. This was the case during the BMD in the early 1980s, and the broad

consultation regarding the desirability of geological disposal of radioactive and highly toxicological waste in the early 1990s. Local residents were also consulted by COVRA in the search for a suitable location for the interim aboveground storage of radioactive waste.

Scientific studies show that public participation can lead to higher levels of trust, but that this is not a causal relationship (cf. Wang & Wan Wart, 2007; OECD, 2017; Liu et al. 2019). The broad societal discussion on energy policy (BMD) in the Netherlands, for example, has not led to more confidence in the government among opponents of nuclear energy. The government saw the BMD as a public consultation and had clearly indicated in advance that it would not automatically follow the outcome of the BMD. At the start of the BMD, many opponents of nuclear energy had low faith in the government and saw the BMD as fake participation. After the BMD in 1984, they felt reinforced in that opinion when the government ignored the outcome of the BMD, that there should be no further expansion of nuclear energy. This experience still seems to play a role in current debates on RWM (Berkers et al, 2023). In a 2015 study (De Vries et al. 2015), the Rathenau Instituut concluded that there is "limited trust in the government with regard to this specific policy issue" (p. 7), and that there is a lack of urgency to participate because of the absence of actual decisions. The Rathenau Instituut proposed that the best way of bolstering trust and willingness to participate, is "to develop a public participation model whose subject matter and procedural design enjoys widespread support" (De Vries et al., 2015, p. 15), and concluded that decision-making on long-term RWM requires a more extensive, long-term and systematic process of public participation. To this end, it proposed the following: 1) the development of a shared plan for public participation, 2) the tailoring of issue-based participation clusters, and 3) periodic reflection to deviate from the plan if necessary.

Public participation has in fact become obligatory following the 1998 Aarhus Convention (UN 1998) and through the 2011/70/Euratom directive (European Council, 2011) and Dutch legislation (Akerboom, 2023). Rather than serving as blueprints for the participatory process, these guidelines and regulations should therefore be seen as 'minimum standards'.

2.4 Conclusions

Since the materialization of NPPs in the 1960s and 1970s, political and societal debates on radioactive waste and nuclear technology, in particular nuclear energy, have become entangled. This has made long-term RWM a sensitive issue. While

the government opted for the further development of nuclear power since the opening of the nuclear power plant in Borsele in 1972, the 1986 Chernobyl accident put a stop to such plans. Recently, the political discussion on nuclear energy has resurfaced. This might influence the long-term management of radioactive waste. The entanglement is also visible from an institutional point of view. For example, the Nuclear Energy Act regulates the licensing of nuclear installations and the safe management of radioactive materials, including radioactive waste. And the division of ministerial responsibilities has shifted because of a perceived conflict of interest between the fields of nuclear energy, and nuclear safety and radiation protection, including RWM.

Over the years, societal resistance against various waste management options, such as disposal into the deep sea and exploratory drillings for geological disposal in salt layers, has influenced the political decision-making process regarding long-term RWM. Since 1984, the radioactive waste policy has resulted in the establishment of an above-ground storage facility, after which geological disposal is foreseen either nationally or internationally. The National Program in 2016 stated that a decision on a final GDF should be taken around 2100. The possibility is left open to deviate from this scenario—both in terms of the timeframe and disposal method. In this way, future generations should not be left with an unreasonable burden. In addition, various policy principles and requirements have been formulated over the years, and a legal framework has been developed that provides guidelines for the decision-making process that lies ahead. Moreover, over the past two decades the ministerial tasks and responsibilities regarding nuclear energy, nuclear safety and radiation protection are split between the Ministries of Economic Affairs and I&W, which may contribute to the checks and balances in the field of RWM.

Although there is a National Program and a suggested timeline for RWM, the road to a final solution is only partly worked out. The Dutch policy of long-term above-ground storage, followed by a GDF, is not only hailed but also criticized. It is seen as good governance and as a good practice in terms of safety and communication with the public. On the other hand, parties such as the European Commission, societal organisations and the Rathenau Instituut are concerned that the century-long period for decision-making leads to a decrease in political urgency and willingness to participate and act on the subject. Various parties, such as the NCEA and the Council of the ANVS, therefore recommend using the interim period meaningfully and to concretize and possibly bring forward the decision-making process. The National Program named several issues that should be clarified as part of the decision-making process.

1) Define the optimal period of retrievability,
2) Set up criteria to reserve potential search locations for a GDF,
3) Clarify options for maintaining the necessary knowledge landscape, and
4) Concretize the role of public participation within research and various national and decentralised political decision-making processes.

The reflections in this chapter on the separate domains bring to light four additional cross-domain issues to be addressed in the decision-making process:

5) Further elaborate the requirement of reversibility of the decision-making process to clarify to what extent decisions should be reversible and how this will be assessed.
6) Develop a long-term, integral and participatory knowledge agenda to support the decision-making process and to keep the science and technology domain vital, now and in the future.
7) Spread knowledge over various (public) institutions, so that there can be an institutionally sound knowledge landscape with sufficient checks and balances. And lastly,
8) Develop a participatory decision-making process for the final disposal of radioactive waste that enjoys broad public and political support in terms of content and procedure to bolster trust and willingness to participate. Laws and regulations in the field of participation can serve as minimum standards.

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