EUROPEAN COMMISSION

Community research

inSOTEC

WORKING PAPER

Identifying remaining socio-technical challenges at the national level: the Netherlands

(WP 1 – MS 3)

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Date of issue: **21/05/2012**

EURATOM

This report is issued by:

Universiteit Antwerpen

ISBN: 978-90-5728-384-0

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0 Preface

This report is part of the research project International Socio-Technical Challenges for Implementing Geological Disposal: InSOTEC (see www.insotec.eu), funded by the European Commission under the Seventh Framework Programme.
This report is a contribution to Work Package 1 of the project, which aims to identify the most significant socio-technical challenges related to geological disposal of radioactive waste. To achieve this objective, a comparative analysis of 14 national programmes will be performed. This report presents the country study of the Netherlands.
Inspired by the field of Science and Technology Studies (STS), the notion of 'socio-technical' broadly refers to an understanding of social and technical aspects being interwoven and mutually influencing; definitions of the technical and the social are shaped in a dynamic, historical process of co-development (e.g. Latour, 2004). Throughout this report, we explored the notion by means of a description of three in our opinion prevailing socio-technical challenges for the Dutch case (section 2, 3, 4) and throughout a dedicated, more general concluding chapter (section 5). The identification of prevailing socio-technical challenges in the Netherlands is based on a review of relevant literature and publications, the revision of research programs, and the exchange with key actors through interviews. In order to consider a broad spectrum of views on socio-technical challenges in Dutch waste management activities, four interviews have been conducted, with representatives of the implementer, industry, an NGO and the Ministry of Economy.
We gratefully acknowledge all the people who collaborated in this work through interviews, responding to questions in e-mails and providing research material.

1 General introduction to the Dutch nuclear context

1.1 Nuclear capacity

The Netherlands has one nuclear power plant (NPP) in operation with one pressurised water reactor in Borssele. This NPP is owned by EPZ (Elektriciteits-Productiemaatschappij Zuid-Nederland), an electricity producer with one public and one private shareholder, which are at the same time its two clients. In 2008 this 482 MWe Borssele power reactor accounted for 3.8% of the Dutch electricity production (World Nuclear Organisation, s.d.). In addition there is one shut-down NPP, the Dodewaard boiling water reactor, which is at an advanced stage of decommissioning.
The country has an enrichment plant, Urenco (Uranium ENrichment Corporation) located in Almelo. Furthermore there are three research reactors in operation: a high flux reactor that also produces medical isotopes, located in Petten and owned by the European Commission Joint Research Centre, a low flux reactor owned by ECN (Energiecentrum Nederland) also in Petten, and a research reactor at Delft University of Technology.

1.2 Main legislation and regulation

The basic legislation governing nuclear activities is set out in the **1963 Nuclear Energy Act**. This lays down the elementary rules in the nuclear field, includes provisions for radiation protection, designates the different competent authorities and outlines their responsibilities. It also covers the principles of Radioactive Waste Management (RWM), together with notably the **1984 'Note Radioactive Waste'**[1] (short for 'Radioactive Waste Policy in the Netherlands – an Outline of the Government's position', VROM, 1984), the **1993 Cabinet Position on Underground Disposal**[2] (Alders, 1993), and the **2002 Radioactive Waste Management Policy Perspective**[3] (van Geel, 2002) (OECD, 2009).

In 1994 the Dutch parliament voted to phase out early, in 1997 the government decided to shut down the Borssele NPP at the end of 2003. In 2000 this decision was annulled by the Council of State. In 2003 the shut-down was postponed to 2013 and in 2005 the phase-out decision was abandoned. In 2006 it was decided that the reactor would be allowed to operate until 2033.[4] In 2009 the idea of a building a new, second reactor in Borssele was officially put forward. Seemingly the events in Fukushima did not influence the political and public opinion about this new reactor proposal. Nevertheless, today the proposal is put off, mainly due to financial (investment) issues.

1.3 Main actors

In 1963, when the Nuclear Energy Act came into place, its focal interpretation was the promotion of nuclear energy, which is why the minister for economic affairs became the prime responsible. After the decision to phase out in 1994 the emphasis shifted towards environmental and safety aspects and radiation protection. In line with this shift and the good governance rationale of a division between promotion and supervision, prime responsibility for the act was moved to the minister of environment (minister for Housing, Spatial Planning and the Environment (VROM)) in 1999 (KFD, 2008, p.47).

However, in 2010, following the formation of a new government, ministries were reorganised and policy fields relocated, among which the nuclear dossier. Currently the minister of Economy, Agriculture and Innovation (EL&I) is once again the prime responsible for all nuclear activities. However, the regulatory body, the Nuclear Safety Department (KFD)[5], remained to be part of the ministry of infrastructure and environment (interview Ministry, 2011).

The minister for finance is in charge of nuclear third liability and compensation for nuclear damage. The minister for foreign affairs coordinates international cooperation in the nuclear field (OECD, 2009).

[1] Nota Radioactief Afval
[2] Kabinetsstandpunt inzake Opbergen van afval in de diepe ondergrond
[3] Beleidsstandpunt onderzoek radioactief afval
[4] See: www.world-nuclear.org/info/inf107.html (Accessed: 12/12/11)
[5] Kernfysische Dienst

The Central Organization for Radioactive Waste (COVRA) is in charge of implementing the Dutch policy with regard to radioactive waste.

Apart from the other actors outlined throughout section 1.1, it needs to be mentioned that the Netherlands has a rather emancipated civil society in general, and an environmental movement that has proved its strength not in the least in the framework of anti-nuclear campaigning.

1.4 Radioactive Waste Management

All Dutch radioactive waste is currently centrally stored at aboveground facilities of COVRA, situated next to the Borssele NPP, flanking the Westerschelde estuary.
COVRA is a non-profit company under private law, which means it obtains no structural financial support from the government. When founded in 1982, 90% of the shares were owned by the main waste producers and 10% by the State. Following the privatisation of the electricity market and the decision to phase out, COVRA became a fully state owned company in 2002.
Its mission is to permanently care for all the radioactive waste in the Netherlands. This means the waste resulting from the reprocessing of spent fuel (returning from Sellafield, UK where the spent fuel from Dodewaard was reprocessed, and from La Hague, France where the spent fuel from Borssele is reprocessed), the conditioned spent fuel rods from the research reactors, the other waste from all of the reactors (including the waste produced in industries responsible for uranium mining, enrichment, and fuel fabrication for these reactors and decommissioning waste) and a variety of industrial, medical and laboratory waste (van der Zwaan, 2008). It is classified into Low and Intermediate Level Waste (LILW), (Technically Enhanced) Naturally Occurring Radioactive Materials ((TE)NORM) and High Level Waste (HLW) (OPERA, 2011d, p.8). An overview of the estimated inventory and disposal facility dimensions can be found in Annex 1.
COVRA's mission entails the collection, conditioning and storage of all these types of radioactive waste, the reservation and management of the financial means for all aspects of surface storage and final disposal, the coordination of the national research and participation in the international collaborations on final disposal.[6]

The baseline of the Dutch RWM policy dates back to 1984 (with the 'Note Radioactive Waste') and is fairly straightforward:

- **Centralized, long-term interim storage** in dedicated buildings at COVRA is intended to last for at least 100 years according to the so called 'IBC criteria' (Isolation, Management, Control)[7];
- During this storage time, funds are built up and research is carried out for a final option, preferably in **international collaborative programmes**;
- Eventually **retrievable, deep geological national or international disposal** is foreseen.

[6] www.covra.nl (Accessed (Accessed: 12/12/11)
[7] Isolatie, Beheer, Controle

The evolution of Dutch RWM can be told along the lines of three major research initiatives (OPLA, the CORA study and the recently started OPERA), the accompanying policy documents, and the socio-political context from which these programmes originate.

Table 1: Overview of the main RWM research programmes in the Netherlands

OPLA (1985 - 1989) stands for 'Disposal on Land'.[8] This research programme was set up with the aim "to gain knowledge and insight with regard to the final and safe disposal of RW based on the currently available mining techniques in rock salt formations with characteristics and volumes that are very likely to occur in the Dutch underground" (OPLA, 1989, p.10, own translation). The proposed site specific research phases never got approved by Parliament. The main conclusion is that disposal of RW in Dutch rock salt is in principle both technically feasible and acceptable in terms of safety. One of the advises drawn from the report is nevertheless that there exists no need to proceed to final disposal on the short term because of the presence of prolonged interim storage at COVRA.
The context and the outcome of the study thus clearly reflect the ***difficulties related to national, site specific disposal research***.

CORA (1996 - 2000) is the acronym for the 'Commission on the Disposal of RW'.[9] The research programme of CORA replaced OPLA after the 1993 Cabinet Position on Underground Disposal, which added the explicit condition of permanent retrievability. It was fully focussed on the technical feasibility and safety of retrievable storage and disposal techniques, both aboveground as well as underground, in both salt and clay. Although in principle no prohibiting factors were found to the technical feasibility of retrievability, it is stated that retrievability is easier for a surface storage. Because this option lacks natural multi-barrier and fail-safe features, the study points out that eventually underground disposal will be necessary, for which permanent ***retrievability*** cannot be guaranteed.

OPERA (2011 – 2016) stands for the 'Research Programme on the final disposal of RW'.[10] In light of prolonged national interim storage and intensifying deliberations on potential international disposal, its aim is not to reach a concrete, national implementation strategy on the short term. The programme is focussed on reducing existing techno-scientific uncertainties, actualizing cost estimates for financial assurances, maintaining national knowledge and know-how, as well as scoping the field of potential stakeholders, all on a ***generic level***. Focus will this time be on the geological formation of Boom clay.

[8] Opberging te Land. Other options, for instance seabed disposal, were studied around the same time throughout more limited research programmes. This explains the seemingly contradictory name OPLA, "Disposal *on Land*", for a research programme that did indeed focus on the underground.
[9] Commissie Opberging Radioactief Afval
[10] OnderzoeksProgramma Eindberging Radioactief Afval

Overall, two issues stand out for the Dutch case of RWM:

- the smallness of the Dutch nuclear programme and thus the **relatively limited amount of both RW and RWM funds**
- the **taboo on all location specific issues** related to RWM

Keeping this background in mind, the actual RWM programme in the Netherlands can be described as "really still in its infancy" (interview Ministry, 2011). "No final solution is defined yet, in the sense that we do not have a location, a geological host formation, nor a final disposal concept yet" (interview COVRA, 2011).

1.5 Research and debate

The Netherlands is well known for its 'polder model', a governance model in which all parties voice their opinion and discuss until consensus is reached. This generalized description also holds for the nuclear debate, but only to a certain degree. This undoubtedly has to do with the socio-technical complexity of the matter of geological disposal of RW.

From the mid-seventies onwards, plans for nuclear new build led to a real political stalemate between industry and government on the one hand, and anti-nuclear social movements on the other. Consequently, the government organised a public debate on this sensitive issue. 'The Societal Discussion Energy Policy'[11], which became commonly known as 'the Broad Societal Discussion' (BMD)[12], took place between 1981 and 1984. The ultimate aim of this ambitious initiative was to ask the Dutch citizens about the future energy policy in the Netherlands and notably the role for nuclear therein. Thousands of public gatherings were organised, hundreds of schools dedicated lessons to energy, a dedicated newspaper with 1.1 million copies was distributed, and several meetings with experts took place (Laka, s.d.).

From the mid-eighties onwards it was acknowledged that RWM requires fundamental debate, beyond the technocratic formulation of quantitative dose limits. Following the debate about the production of nuclear waste (the BMD), between 1990 and 1993 another fundamental discussion was organised about whether the use of the underground for waste disposal is justified in principle (in line with the National Environmental Policy Plan (NMP-action 62)[13]). From a participatory point of view this debate was much less ambitious than the Broad Societal Discussion, but it did provide a forum for thorough and in depth reflexion.

Although it was agreed that no decisions would be made related to nuclear energy by the government at the time, various ministers ordered a study in 1992 "in order to allow the following cabinet, if so desired, to express itself on issue of nuclear energy" (Andriessen et al., 1993, p.47). The

[11] Maatschappelijke Discussie Energiebeleid
[12] De Brede Maatschappelijke Discussie
[13] Nationaal MilieubeleidsPlan, Tweede Kamer, 1988-1989, 21 137, nrs 1-2, actie 62

results are published in 'the Dossier Nuclear Energy'[14] which was sent to Parliament in 1993. The report is focussed on "the main questions that preoccupy society", namely safety, waste, proliferation, environment, and societal acceptance (Andriessen et al., 1993, p.47). The main aim of this document was to once again renew the nuclear debate (Oosterheert, 1993, p.2).

The processes and contents of the examples given have been studied and commented extensively.[15] We mainly want to indicate here that the Dutch case does show cognizance of the complex interaction between technical and social challenges related to RWM. Paradoxically however, when it comes to the integration of such debates through actual policy and research, few success stories can be told. Early contestation around test drilling led to a complete taboo on all location specific research, let alone policy making (cf. also section 2.3). The results of the Broad Societal Discussion were ignored by the government at the time.[16] Following the Dossier Nuclear Energy, Oosterheert wrote "There seems to occur some sort of vacuum, more a saturated discussion than a renewed debate" (Oosterheert, 1993, p.7, own translation*).* 'Nuclear' in general was shunned by every consequent government up until the recently elected one (interview Ministry, 2011). The discussion about the use of the underground led to the notion of retrievability, which remains up until today ill-defined and both socially and technically contested. The directly related demands about the preservation of knowledge and know-how and the demand for continuous monitoring and control have not been taken up systematically. It remains to be seen if and how the recently launched RW research programme, OPERA, and the evolution of the proposal for a new reactor in Borssele will change these observations.

1.6 Timeline aid[17]

1969: The first reactor is put into operation in Dodewaard.

1972: The 'Scientific Council for Nuclear Energy '(WRK)[18] points out that RW will have to be stored, and indicates salt domes as a potential option.

1973: The second reactor is put into operation in Borssele.
Heavy demonstrations take place against the Dutch participation in an experimental breeder reactor project at Kalkar, Germany.

[14] Dossier Kernenergie

[15] For an evaluation the Broad Societal Discussion, see e.g. Hagendijk et al., 2004. For an elaboration on the search for a justification criteria and the principle debate about the use of the underground for waste disposal, see section 4.1.

[16] As opinions throughout the BMD diverged heavily, it was hard to formulate a common advice. Apart from a general plea for renewables, the following summary with regard to nuclear was made by the Steering Committee: the two existing reactors do not have to be closed, but we should refrain from building new reactors and the issue of nuclear waste should get careful attention (de Brauw, 1984). In 1985 the government ignores the outcome of the BMD and decides that two (in first instance) new NPP's will be build. In 1986 the BMD advice eventually does get taken up, but only under the influence of Chernobyl.

[17] Based mainly on Laka, s.d.

[18] De Wetenschappelijke Raad voor de Kernenergie

1975: The 'Interdepartmental Commission for Nuclear Energy' (ICK)[19] recommends the option of geological disposal in salt.

1976: Per letter the government informs 2 provinces in the North of the country about the suitability of their underground for exploratory drilling, leading to intense and broad resistance.

1978: Under influence of continued local resistance accompanied by heavy general anti-nuclear protest, the Parliament accepts a motion to postpone test drilling. The Government announces a broad public consultation on nuclear energy.

1981 - 1983: The 'Broad Societal Discussion' takes place. The resulting advice to refrain from building new reactors is ignored. Only under the influence of Chernobyl is it eventually taken up.

1981: The Commission 'Integral National Research on Nuclear Waste'[20] (ILONA) is installed. Its aim is no longer solely to investigate final disposal in the Netherlands, but to also take into consideration international cooperation and disposal and to investigate the possibilities of centralized storage in the Netherlands.

1982: The Central Organisation for Radioactive Waste (COVRA) is created, entrusted with the collection, treatment and storage of all categories of RW produced in the Netherlands.

1984: The Government's 'Note Radioactive Waste' (VROM, 1984) is sent to Parliament, summarizing the basics of the Dutch RWM, including the choice for prolonged interim storage.

1985 - 1989**:** The ILONA Commission launches the 'Disposal on Land' programme (OPLA) (cf. table 1).

1990 - 1993 : A principle debate takes place on whether the deep underground can and should be used for disposal of toxic, non-processable waste (nuclear and chemical).

1993: Based on the previous debate, the Government formulates the Cabinet Position on Underground Disposal of highly toxic waste (Alders, 1993). The main feature of this document is the newly formulated condition of retrievability.
The Dossier Nuclear Energy' is published.

1995 - 2000: The ILONA Commission replaces OPLA with the 'Commission Disposal RW', CORA (cf. table 1).

2001: After the publication of the end report of CORA, regional authorities express their continued resistance against GD.

2002: Based on the CORA studies and the consequent advice of The ILONA Commission, the 'Radioactive Waste Management Policy Perspective' (van Geel, 2002) is offered to Parliament. It displays no divergence from the previously outlined RWM policy, i.e. prolonged interim storage and retrievable GD. International collaboration is highlighted even more than before.

1997: The Dodewaard NPP is shut down, mainly because it was no longer profitable.
The Kyoto protocol is signed.

2003: The shut-down of Borssele is postponed to 2013.

2006: The shut-down of Borssele is postponed to 2033.

2009: Energy company Delta hands in a first note for a new (second) reactor at Borssele; the Environmental Impact Assessment is started.
The Research Programme on the final disposal of RW, OPERA, the successor of CORA, is initiated (cf. table 1).

[19] Interdepartementale Commissie voor Kernenergie
[20] Commissie Integraal Landelijk Onderzoek Nucleair Afval

2 Surface storage and / or geological disposal

2.1 One centralized location for all radioactive waste

The Netherlands forms no exception to the common observation that a well-considered radioactive waste management plan was no precondition for the development of a nuclear programme. Throughout the sixties and seventies, LILW was dumped in the Atlantic Ocean (until 1983), HLW was stored where it was produced, and spent fuel was sent abroad for reprocessing with no clear arrangements about returning waste. Quite rapidly however, in light of expanding the nuclear energy capacity (and thus also the production of RW), and due to concerns pressed by the environmental movement, it was realized that these strategies would not be sustainable on the longer term.
In the eighties is was decided to opt for one, central storage / disposal for all radioactive waste, i.e. all different types of RW from all producers. Throughout the reasons given by various actors for this decision, one can detect the socio-technical nature of this choice:

- One location enhances safety (in terms of both environmental and human protection) because the control over, as well as the collection, treatment and conditioning of the waste is organized centrally (VROM, 1984, p.6);
- A centralized approach enhances the clarity of responsibilities and liabilities (interview COVRA, Ministry, EPZ, 2001);
- In light of the limited amounts of waste spread over many producers, a central approach limits the costs of conditioning and storage per unit of RW, while at the same time it allows the application of the most advanced techniques (VROM, 1984, p.6);
- A centralized location enhances the clustering of expertise (interview COVRA, 2011) and the preservation of nuclear know how beyond the life time of the producer (interview EPZ, 2011);
- Last but not least, opting for one, centralized location is practically possible because of the relatively limited amounts of waste: it does not require a mega location like you would need for instance in France to collect the waste of over 50 reactors (interview Ministry, 2011).

Continuing to focus on potential arguments pro centralised storage, two more reasons can be thought of. Firstly, keeping all RW at one location can enhance safeguards and security, as it can enable a better prevention of radioactive sources falling into the wrong hands. Secondly, one location requires only one siting process.
The combination of all these arguments apparently have been judged more important in the Netherlands than potential arguments for decentralized storage, such as reduced transports and burden sharing.

2.2 Reasons for geological disposal

Following international developments, e.g. in countries like the USA and Germany, as well as recommendations by international organisations (Wright, 1981; European Commission, 1982; OECD/NEA, 1982a, 1982b; IAEA, 1983), from the early seventies onwards permanent, geological disposal also came to the foreground in the Netherlands.
From a technical viewpoint, domestic geological disposal is possible in both salt or clay. Based on the following mixture of reasons, rock salt has historically been considered the preferred host formation (OPLA, 1998, p.9):

- because it is available in the Netherlands;
- because it has attractive characteristics for RW disposal;
- because there is a lot of existing experience with mining activities in this formation, most notably in Germany.

The general goal to opt for geological disposal is "long-term isolation of radioactive waste from our living environment in order to avoid exposure of future generations to ionising radiation from the waste" (OPERA, 2011c, p.1). The more specific reasons to opt for permanent, geological disposal were and are diverse, and form in our opinion once again a socio-technical mixture:

- Because adequate removal techniques used for other types of waste are not suitable (e.g. Alders, J., 1993, p.2);
- Because adequate removal techniques for RW (think about partitioning and transmutation (P&T)) are not operational - nor are they soon expected to be (e.g. Oosterheert, 1993, p.5; Van Geel, 2002, p.13; interview Ministery, 2011), and will not change the need for geological disposal (e.g. Van Geel, 2002, p.13; interview COVRA, 2011);
- Because it limits the use of space above ground (Alders, J., 1993, p.6);
- Because it does not oblige future generations to active care (e.g. OPLA, 1989, p.9). Materials moulder away over time (e.g. interview Ministry, 2011) and therefore surface disposals are dependent on institutional control and human maintenance, which can not be guaranteed over time. For geological disposals, because of its multi-barrier system, these issues are less relevant (e.g. CORA, 2001b, p.2; interview COVRA, 2011; interview EPZ, 2011);
- Because the deep underground diminishes the chance of RW becoming the pivot of all sorts of socio-political powers (interview Ministry, 2011);
- Because the deep underground has the capacity to withstand the catastrophic, dynamic natural processes that regularly affect the surface of the earth (CORA, 2001b, p.2).

Summarized, up until today the Dutch government recognizes that storing even relatively small amounts of long-lived radioactive waste at COVRA, while an adequate intermediate solution, is not a sustainable end-solution. Geological disposal thus was and still is considered the only acceptable long-term solution (Van der Zwaan, 2008; interview COVRA, 2011; interview EPZ, 2011). Nevertheless, no dedicated test drilling – let alone actual disposal – has taken place up until now.

Although the environmental movement, albeit often in a silent manner, is not ignorant towards the above mentioned socio-technical arguments in favour of geological disposal, one may detect a highlighting of the social motivations in their negative appreciation of the option: "The idea of geological disposal mainly has to do with political motives. You can cloak it as 'a solution' in order to continue with nuclear energy. More profoundly, there seems to exists a sort of deeply rooted desire to hide such problems away as far as possible, to literally burrow them, far under the surface, so that you don't have to look at it; as to make it invisible" (interview WISE, 2011).

2.3 Reasons for prolonged surface storage

Referring to the USA and West Germany, a preference for the geological formation of rock salt, most notable available in the North of the country, was expressed from the start of geological disposal thinking in the Netherlands. Based on the geological characteristics of salt, the 'Interdepartmental Commission for Nuclear Energy' (ICK) follows this idea in its reports in the seventies. In 1976 the Government writes a letter to two provinces in the North of the country, to inform them of the suitability of their underground for exploratory drilling in five salt domes[21] (Damveld, 2001, p.6). The media immediately jump on the topic, and resistance is intense and broad. The provincial waterworks[22] conduct technical research that goes against the suitability of the suggested salt domes. Action groups come into place. All municipalities refuse.

In 1976 the National Geological Service[23] publishes the "Geological waste disposal program to be carried out in the Netherlands" as part of the Environmental Programme of the European Community. This report displays the polarizing passage: "Feasibility study and general hazard analysis *with the aim to obtain public and governmental acceptance*" (cited in Damveld, 2001, p.59, own italics). In 1977 the province of Groningen writes a clear reply: "There are many reasons to assume that the experiments in question are meant to find the most suitable location. The question whether disposing RW in salt domes is justified, is in fact no longer under discussion" (cited in Damveld, 2001, p.6, own translation). In 1978, under continued local resistance against test drilling, accompanied by heavy general anti-nuclear protest at nuclear fuel production company Urenco, the Parliament accepts a motion to postpone test drilling.

The following citation illustrates how the neglect of the socio-technical character of RWM marked the Dutch RWM from the very early start (cited in Damveld, 2001, p.57, own translation):

> "This announcement [the government letter of 1976 (authors addition)] was (…) not the beginning of the fast preparation of radioactive waste disposal, but the starting shot of a long-lasting conflict between central and local government, between policy supporting research institutes and critical scientists, and between the central governmental policy and groups of concerned citizens. A conflict in which the word 'research' received the connotation of the start of actual disposal. Throughout this conflict test drilling played a

[21] A salt dome is naturally developed cavity in a salt layer.
[22] Waterleidingsmaatschappij Drenthe
[23] Rijks Geologische Dienst

> central role, as well as the choice for some five locations where drilling would take place. Around the theme of test drilling, the conflict sharpened."

The socio-technical nature of the site specific deadlock is furthermore reflected throughout the fact that, for the Netherlands, it impacted not only the RWM policy *process*, but it also directly influenced the RWM policy and research *content* to a certain degree.

In 1981 the 'Commission Integral National Research Nuclear Waste' (**ILONA**) is installed. Its aim is no longer solely to investigate final disposal in the Netherlands, but to also take into consideration international cooperation and disposal (cf. section 3), and to investigate the possibilities of centralized storage in the Netherlands (ILONA, 1989, p.2).

In **1984** the '**Note Radioactive Waste** (VROM, 1984) is sent to parliament, explaining the government policy with regard to RW. This note summarizes the basics of the Dutch RWM, now formally including not only the idea of one, centralized location for all RW, but also of prolonged interim storage:

- The point of departure is that the waste will be managed following the so called IBC criteria: Isolation (from the biosphere), Management (registration and restriction on both the activity and the volume of waste), Control/Inspection (focussed on monitoring)[24];
- All Dutch radioactive waste will be stored on one location by COVRA;
- This central location serves as a long-term interim storage, proportionate for the upcoming 50 to 100 years, until a final disposal is found.

The fact that preparing and siting an interim storage is considered easier than preparing and siting a permanent disposal is not mentioned as such throughout the Note, but it can be read in between the lines (cf. also section 3.1). A RW storage facility can be described as an ordinary industrial installation. The Note states that, besides spatial planning considerations, in fact the sole criterion for a site is the availability of enough space (VROM, 1984, p.10). In 1984 the Commission Location Choice Storage Facility RW (LOFRA)[25] is installed to advise the government about the final decision with regard to a location. Based on the Commission's advice and a location-independent environmental assessment eventually the choice is not made by the government, but left to COVRA. In 1986 COVRA choses a terrain in Borsele, in the close proximity of the NPP. The main considerations once again reflect what we refer to as the socio-technical nature of the choice (COVRA, 1986, p.2, own translation):

- "Minimal mutual safety influence between the facility and the environment
- The location of the terrain with regard to the neighbouring community
- The location of the terrain with regard to the supply of waste
- The most justified as possible choice cost price-technically
- Simplicity and clarity of further planning and procedural steps"

The local community receives some information after all decision have been made, which leads to quite some critique with regard to transparency (Antonisse, 1987; Laka, s.d.).

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[24] Explanation of IBC based on VROM, 1984 and van Geel, 2002, p.6

[25] Lokatiekeuze Opslagfaciliteit Radioactief Afval

Nevertheless, in December 1992 the COVRA offices, information centre and the storage buildings for LILW (named LOG) are finalized, in September 2003 the facility for HLW (named HABOG) is opened. Over the years COVRA seems to have developed an attentive attitude for public perception. The organisation for instance devotes a lot of attention to the visual aspects of its premises, and generally has an open policy towards visitors. "While the production of nuclear waste still constitutes a major reason why the Dutch public remains sceptical about nuclear power, the storage of radioactive waste at COVRA receives little criticism" (van der Zwaan, 2008, p.4).

Coming back to he reasons to opt for long-term interim storage, they are diverse and once again can be described as socio-technical:

- There was no societal and political support for finding a location for a final disposal (interview COVRA, 2011, interview WISE, 2011);
- "Partly due to financial-economic considerations, preference now needs to be given to surface storage" (VROM, 1984, p.1, own translation); the Netherlands has a small nuclear programme generating limited amounts of nuclear waste, and thus time is required to gather the necessary funding for a geological disposal through the (interest on) payments by the producers when they transfer the waste to COVRA (interview COVRA, 2011; interview Ministry, 2011);
- "Advantages of this form [surface storage, own addition] are the manageability and controllability" (VROM, 1984, p.8, own translation);
- "(…) in due course (one should think about storage periods in the order of magnitude of 100 years) the part of the stored LILW that is decayed sufficiently can be removed as non-radioactive waste" (Idem);
- "During the period of storage, options for permanent removal can be further studied, international developments followed up, and perhaps connections can even be sought to a potential international disposal facility" (Ibidem, p.9). By opting for prolonged interim storage, time is bought to think thoroughly about how and eventually where to continue the permanent RWM programme; further technical research is needed (interview Ministry, 2011);
- Also in light of the limited amounts of waste generated, postponing the building of a final, geological disposal with interim storage allows you to limit the time in between building, filling and closing a final disposal, which is less demanding and safer both technically and organisationally (interview COVRA, 2011; interview Ministry, 2011);
- The idea was that the current Borssele reactor would be the last one, so one would wait for all the waste to be ready to be disposed of (interview Ministry, 2011) (taking into account cooling periods for HLW and decommissioning).

Critics are wary towards what they see as a backward rationalization of the decision for prolonged interim storage, e.g. by means of economic arguments. They mention the socio-political impetus as by far the main reason why continuing with GD was impossible. As another motive to opt for interim storage they highlight that there were simply too many remaining uncertainties surrounding GD. An interview with a representative of the environmental movement summarizes the history as follows (interview WISE, 2011):

> RW has always been a major reason to be against nuclear, especially when it became concrete, i.e. when actual methods and sites were looked at. This set the whole country on fire. In the beginning these commotions were not dealt with in a smart way. Government and industry learned from this and certain stakeholder processes were set up. Nevertheless this turned out to be quite complicated. Moreover nuclear energy did not turn out to have a future in the Netherlands. Then they basically just stopped the discussion, it disappeared into the drawers as "we'll see in a 100 years". (…) The choice for interim storage was made because the debate was completely locked in. It was politically impossible to persevere with geological disposal. And the reason that it was completely blocked was the supercilious, technocratic attitude giving the impression of "We understand it, you don't get it, just let us decide for you". Another reason to opt for interim storage was simply that geological disposal wasn't clear yet. There still were quite some technical experts that weren't convinced. That's the story, and this economic argument which makes it all sound very logical and rational, was conveniently made up afterwards only.

3 National and / or international RWM

International research collaborations have taken place from the very early beginnings of RWM thinking, both through bilateral and supranational structures. Nevertheless, joint research needs to be distinguished from joint disposal. International regulation defines the responsibility for RWM within the sovereignty of the nation state. Although it is stated that each country should take care of its own waste, it does not say that this entails a national solution. The main thread in the EU is indeed national responsibility, but leaving open the possibilities for voluntary joint solutions (Berner et al, 2011, p.42).

With regard to a shared repository, broadly two options exist, an 'add on' or a 'shared' scenario (interview COVRA, 2011), i.e. "an international project, or the extension of a national project (…) to accept additional material from other countries" (IAEA, 2004, p.11). In the earlier years, "the creation of an international repository through the commercial extension of national programmes was judged to be a more credible route than the formation of an international project" (IAEA, 2004, p.11, referring to a 1987 OECD NEA study[26]). However, as time evolved and countries elaborated their national RWM programmes, quite some nation states – like Sweden, Finland, Germany and France – have established an import ban regulation. From this point of view, a 'shared scenario' among countries with limited amounts of RW may be considered more plausible, since it neutralizes the suspicion and limits the compulsion of such countries wanting or needing to get rid of their waste in larger nuclear energy producing countries (interview COVRA, 2011). In any case, for both options a broad range of factors including technical (safety), institutional (legal, safeguards), economic

[26] OECD NEA (1987). International Approaches to the Use of Radioactive Waste Disposal Facilities, A Preliminary Study. OECD, Paris.

(financial) socio-political (public acceptance) and ethical considerations needs to be taken into account (IAEA, 2004, foreword).

The Netherlands did not only engage in international research collaborations[27] from the very first start of its RWM programme, but also embraced the idea of an actual shared repository early on. Already in the eighties the Netherlands took the initiative within the framework of the OECD NEA to conduct a study on the possibilities of an international repository (ILONA, 1989, p.2, cf. footnote 23). Also on the national level, with the instalment of the ILONA Commission in 1981, RWM research was outlined to take into consideration not only the Dutch territory, but also international cooperation and disposal (ILONA, 1989, p.2; VROM ,1984, p.9). The option of looking to join a potentially internationally set up disposal facility is also taken up in the 1984 'Note Radioactive Waste' (VROM, 1984, p.9). The Note nevertheless also stipulates that research on national geological disposal will not be abandoned, to make clear that this international interest in combination with prolonged interim storage does not entail a 'wait and see' policy. As also pointed out throughout the previous section on prolonged interim storage, convincingly substantiating this statement remains a challenge for the Netherlands.

3.1 Reasons for internationally shared (research on) repositories

Following the Note Radioactive Waste, in **1985** the ILONA Commission launches the 'Disposal on Land' programme (**OPLA**) with the aim "to gain knowledge and insight with regard to the final and safe disposal of RW based on the currently available mining techniques in rock salt formations with characteristics and volumes that are very likely to occur in the Dutch underground" (OPLA, 1989, p.10, own translation). Notice is taken from the elaborate research on clay in neighbouring country Belgium, focussed on a clay layer (Boom clay) that also extends into the Netherlands. Nevertheless, following the WRK's and ICK's recommendations, emphasis is put on rock salt as the preferred geological formation for national, final disposal.

Three research phases are proposed under OPLA. Only phase 1, a technical-scientific feasibility study to determine the preferred disposal method, gets approved by parliament, with the explicit precondition that no fieldwork would be undertaken (OPLA, 1989, p.9). The proposed phase 2 (geological and hydrogeological preliminary investigations) and phase 3 (location specific research, test drilling) thus do not get approved yet, but will be reviewed after the completion of phase 1.

Accordingly, research is conducted based on laboratory research, literature study, modelling with (publicly) available data, and participation in foreign and international research projects. 38 locations are investigated on paper, of which 26 are found appropriate for the disposal of RW and 17 for the actual implementation of a disposal mine (Laka, s.d.). The main conclusion of OPLA phase 1 is thus that disposal of RW in Dutch rock salt is in principle both technically feasible and acceptable in terms of safety, and that the continuation of research is therefore justified (OPLA, 1989, p.19). In both the geological and the geo-hydrological part of the research it is stated that location specific fieldwork is

[27] For instance with Germany, Spain and France with regard to disposal in rock salt during the time of OPLA (CORA, 2001a, p.88).

necessary in order to obtain a definitive safety evaluation (OPLA, 1989, p.16). “Conclusions are not specified to concrete locations, but results are formulated more generally and in terms of expectancy” (OPLA 1989, p.19, own translation).
Following the OPLA report, the ILONA Commission summarizes its advice to the minister as follows (ILONA, 1989, p.1, own translation):

- “There exists no need to proceed to final disposal on the short term because of the presence of prolonged interim storage (with COVRA).
- It is not possible to proceed to the second phase of OPLA, where orientation field research is foreseen; first additional studies to verify assumptions and models used in the first phase and to further describe the available salt occurrences are needed.
- No content based government position needs to be taken.
- The report is sent to parliament for its information”.

The end conclusion thus is ambiguous: socio-technically, further research clearly is needed, but whereas from a science-technical point of view, this complementary research would need to consist of field work, this would seem impossible from a national socio-political point of view.
Here the international level comes in: for in situ research, the joining up with international research is advised, because national research would entail “disproportionately extensive and costly experimental work” (OPLA, 1989, p.19, own translation) and because “In the current stage of research, […] the possibility to make a [more site specific, authors addition] selection is to an important degree limited by a lack of site specific information. This is the result of an embargo on the use of existing data on the one hand, and the fact that no site specific research could be conducted on the other hand” (OPLA, 1989, p.20, own translation). Also in subsequent official documents, the siting issue is mentioned as a crucial reason not to complete the initially proposed, national OPLA programme: “The second phase [of OPLA, own addition] would consist of fieldwork, such as test drilling in salt domes. Nevertheless, at the time the government, also because of the societal resistance towards geological disposal, did not consider it acceptable to proceed to this” (CORA, 2001a, p.19, own translation) (remember also section 2.3).
Instead of digging into this socio-technical challenge, the second (field work) and third (site specific research) proposed phase of OPLA are abandoned and a phase 1A is inserted, to further limit existing conceptual scientific uncertainties. The results of this complementary research are published in 1993. There is no more talk about test drilling, and the conclusion does not differ from that of 1989: the feasibility of disposal in salt is confirmed, the need for further research underlined as justified, and the importance of international cooperation highlighted.

After OPLA, the ‘Commission on RW Disposal’, **CORA** is established in **1995**, to coordinate a research programme once again focussing on the technical feasibility of (this time retrievable, cf. section 4) geological disposal. The research programme runs from 1996 to 2000. Once more the recommendations stress the importance of international cooperation and the need for further research, focussing on in situ research in an underground research laboratory (URL) (VROM, 2002, p.12). The similarities continue: the smallness of the Dutch nuclear programme and thus the limited amount of RW hardly justify such an URL in the Netherlands itself, nor would it be expedient in light of the insufficient societal support for nuclear energy (Idem).

Although the regional level is not given an opportunity to officially react to the CORA end report, one of the provinces that has a potentially suitable geology (Drenthe) sends its comments to the minister on its own initiative. The letter indeed stresses that the CORA study does not offer a reason to revise their vision: both GD and experimental drilling to this aim remain repudiated. “Because of its principle rejection of the disposal of waste in the deep underground, the Province of Drenthe will by all possible means offer resistance against activities that aim at preparations for GD” (ter Beek et al., 2001, p.2, own translation).

Whereas the CORA study itself mainly motivated international, joint *research*, the governmental advice following the CORA report translates this advice into a motivation for the potential of an actual regional *repository* (van Geel, 2002, p.12). Moreover, following the CORA study and the governmental decisions based on this study, also with regard to the confirmation of prolonged interim storage, the Netherlands pleads for more policy freedom in the framework of the European Commission, where at the time the first proposals towards fixed national time schemes for geological disposal were put on the table (Van Geel, 2004, p.4-5).

In subsequent years after CORA, no major changes or activities are to be noted within the Dutch RWM at the national level. A noticeable role however was taken up at the international level, where notably COVRA became a prominent advocate of the idea of shared repositories. COVRA became the president of the Assembly of Members from ARIUS, the Association for Regional and International Underground Storage.[28] COVRA also was one of the driving forces behind the EC SAPIERR-II project (Strategic Action Plan for Implementation of Regional European Repositories, 2006-2008), throughout which economics, (legal) design, public and political opinion, and safety and security in relation to a European repository were studied. Together with ARIUS, since 2008 COVRA manages the non-profit working group ERDO (European Repository Development Organisation), which focuses on strategic and organisational issues.

In addition to this international interaction, bilateral interaction with Belgian was sought, mainly in function of the URL in the North East of Belgium.[29] In **2008**, a ‘Network Disposal RW’ (**NORA**)[30] workshop was organised, gathering Dutch and Belgian actors in the field of RWM research to substantiate the process and content of further joint research. During this workshop the idea of an internationally shared repository was put on the table as the most attractive scenario by various Dutch actors (Poley et al., 2008). A scenario in which the Netherlands would build an own, national disposal was presented more as a back-up scenario, in case the scenario of an international final disposal would fail (Poley et al., 2008, p.5).

[28] ARIUS developed out of the controversial and eventually abandoned Pangea project, a commercial initiative with the aim to concretize an international disposal looking in particular at regions of Australia.

[29] HADES, an URL operated by EIG EURIDICE (European Underground Research Infrastructure for Disposal of nuclear waste In Clay Environment), an Economic Interest Grouping (EIG) involving the Belgian Nuclear Research Centre SCK•CEN and the Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/ NIRAS).

[30] Netwerk Opberging Radioactief Afval. In fact this acronym was already used before, at the time of OPLA, when it referred to research on seabed disposal (Noorzee Opberging Radioactief Afval).

Investigating the contextual debate surrounding internationally shared repositories reveals an interesting mix of socio-technical arguments, that shows the case is a subtle example of the mutual shaping between technology and (international) society.
We firstly list some of the main argumentations for striving for an optimal supra-national approach as they were formulated by Dutch actors throughout the years:
A shared repository

- enhances quality control and safety through research harmonisation and standardization (CORA, 2001a, p.87, van Geel, 2002, p.12);
- spurs the efficient use of necessary financial means (CORA, 2001a, p.87); it makes GD as a whole cheaper, which also enables more scope to make the idea attractive for any host country (Poley et al., 2008);
- inherently acknowledges the fact that environmental effects of a disposal may be transboundary (CORA, 2001a, p.87);
- allows the amount of the final disposals to be limited to the most optimal locations (van Geel, 2002, p.12);
- enables more efficient disposal exploitation (Idem);
- reinforces institutional (supranational) control (Poley et al., 2008).

The ERDO WG leaflet gives a detailed overview of international, national and local "benefits of working together" in the framework of a shared repository. It repeats some of the arguments already mentioned, but adds new ones too that can also be interpreted as socio-technical (ERDO, s.d.):

"Internationally

- increased national visibility and influence in addressing a widely acknowledged issue of global environmental protection and nuclear security
- contributing to Europe-wide investment savings of several billions of EUR
- increased influence in European and international agencies dealing with nuclear energy and nuclear safety
- increased influence on suppliers of nuclear technologies and fuels

Nationally

- clear demonstration of a credible approach to responsible management of national radioactive wastes
- reduced R&D burden
- increased, pooled resources to develop a realistic and timely solution
- large economic incentives and infrastructure improvements to the host country
- access to wider skills and technology

Locally

- involvement in modern, stakeholder-led approaches to solving environmental problems
- increased influence of local host communities in national environmental decision-making
- large economic and infrastructure benefits to the host communities, both today and for many decades to come"

3.2 Reasons for national (research on) repositories

Already in 1987 the previously mentioned OECD NEA study about internationally shared repositories (cf. footnote 26) "concluded that there were no apparently insurmountable safety, technical, economic or institutional obstacles to serious consideration of the concept. Nevertheless, because of slow progress in the development of national repositories, the committee did not believe that the time was right in 1987 to embark on a comprehensive generic study" (IAEA, 2004, p.11-12).
The following thoughts are interesting in this regard. Due to economic, technical as well as environmental considerations, regular waste management has evolved in line with an 'economies of scale' rationale and steadily developed from a strictly local to a regional, national and European affair. General waste management has become an international business in which multiple actors and various industries try to find mutual benefits. The nuclear sector, however, due to various reasons, has historically always been a more or less isolated industry. This is for instance clearly reflected in the treaty of the European Community (Euratom). Moreover, within the nuclear industry, international collaborations are intense in all steps of the nuclear fuel cycle (reactor manufacturing, fuel production, …), apart from actual waste disposal. In RWM principles like **proximity, self-sufficiency** and **sovereignty** continue to play a dominant role. Against the background of regular waste management evolutions and in contrast with the international character of all other steps in the nuclear fuel cycle, this can be considered a bit strange (interview COVRA, 2011).

Both COVRA and the government emphasize that a precondition for adhering to the idea of international disposal is the preparedness to host this international disposal on one's own territory, and thus a willingness to accept foreign waste (interview COVRA, 2011, interview Ministry, 2011). Nevertheless it is also admitted that, for the time being, for any European minister to officially take this stance would mean political suicide (interview Ministry, 2011, interview EPZ, 2011). This is also indicated by the fact that no national declaration of willingness to be a repository host is necessary to join the exploratory ERDO-working group (ERDO, s.d.).[31] The ILONA Commission already indicated that the most important hindrances to shared repositories are located at the level of **political and public opinion** (ILONA, 1989, p.2), and during the NORA workshop siting is also described as one of the most undermining issues (Poley et al., 2008, p.7). A shared repository indeed does not eliminate the **siting** issue, it relocates and postpones it, but also makes it more complex. Countries like Finland and Sweden show that if the idea of including foreign waste is not integrated in the RWM process from the start, the risk of jeopardizing the progress made by adding it later, is judged to high. At least intuitively the idea of a shared repository is connected more to export than to import of waste for a country like the Netherlands (and probably every other Western European country with an interest in the idea). Communication is also not always that straightforward in this regard. The corporate folder of COVRA for example gives the following message: "After that 100 year period of storage it

[31] Current members to the ERDO WG are Austria, Bulgaria, Ireland, Italy, the Netherlands, Lithuania, Poland, Romania, Slovakia and Slovenia (ERDO, s.d.).

will be investigated whether the part of the waste that is still active by then can be definitively disposed in the own country. By then, perhaps international solutions may be available (…)”.[32]

At the NORA workshop mentioned earlier, Belgian participants communicated the message that the idea of a regional disposal is not under discussion in Belgium (Poley et al., 2008, p. 2, p.5). It was pointed out that collaborations are valuable only when they lead to a win/win situation. **Technical and regulatory differences** between countries were also mentioned as a hindrance, e.g. with regard to retrievability and remote monitoring (Idem). The waste **transports** that unavoidably accompany the implementation of a shared repository were also mentioned as a more negative factor (Poley et al., 2008, p.7). International studies also mention that shared repositories may lead to a greater variety of waste sources. "… **waste acceptance criteria** might be more complex due to differences in the nationally employed conditioning technologies and waste packaging, and a greater variety of waste handling equipment might be required" (e.g. IAEA, 2004, p.25). In light of the **scientific quality** one may also take a critical stance towards only seeing advantages in joining research forces, as this may diminish scientific values such as 'independent' comparative studies and expert reviewing.

The environmental movement agrees that the idea of shared repositories is not irrational, but also raises some critical remarks. For one, they point out that it can turn out to be an ethically risky idea. Countries that up until now have indicated some potential interest in being a host, have always been weak states that are in urgent need for money and / or do not have a developed civil society. The Dutch government is alert to this **ethical concern** of not allowing a connection between poverty and accepting foreign waste (interview Ministry, 2011). In a way the shift from commercial to voluntary cooperation answers this concern, but the debate on compensation needs to carefully guarded. Moreover, it is pointed out that with regard to **controllability and manageability**, in comparison to large, diffuse structures, small structures are known to be more capable to keep an overview of things, are generally more robust on the long term, and have a larger sense of responsibility for the common good (interview WISE, 2011).

4 Reversibility and Retrievability

4.1 The search for a 'justification criterion'

The notion of retrievability appears for the first time in the Note Radioactive Waste in 1984. There it is stated that disposal in cavities in salt is in principle irretrievable, which does not completely comply with the IBC criteria. No further attention is devoted to the issue. The Note simply continues with stating that all the RW could be disposed in a salt mine, with shafts, which would enable the manageability and controllability of the waste during the operational phase of the of the mine (VROM, 1984, p.9).

[32] Available from www.covra.nl/cms-file/get/iFileId/2394

OPLA, the RW research programme which ran from 1985 to 1989, was centred around radiation-hygienic safety (OPLA, 1989, p.10 - 11). To assess the safety of the different options and scenarios under consideration, a so called 'justification criterion' was added, mainly by means of the formulation of a radiation protection norm (Damveld, 2001, p.89; OPLA, 1989, p.10). Risk was classically defined as probability x consequence (OPLA, 1989, p.11) and health risks were judged as this dose exposure chance x individual decease risk (Ibidem, p.13). Reversibility and Retrievability (R&R) are not discussed, and the disposal of LILW in salt cavities is also investigated. Retrievability is mentioned only as follows in the summary of the final report: "(…) in line with the programme-design of 1984, if provisions for long term retrievability are inconsistent with the target of long term isolation of the waste, the latter prevails" (OPLA, 1989, p.10, own translation).

Quite rapidly the inadequacy of a scientific, quantitative norm related to decease risk in the framework of 'justification' was realized, also due to resistance from the public. "In the course of time, both government and parliament have observed that apart from mainly natural scientifically orientated research activities, addressed to the question if the use of the deep underground is possible for the disposal of RW, there exists a need for a testing criterion to test whether such a removal technique for RW is desirable societally and according to policy making" (Alders, 1993, p.4, own translation). In 1987 the Minister of Environment at the time publishes the 'Baseline note' in behalf of the development of a test criterion for the underground disposal of RW'.[33] This test criterion was to be developed *independently* of the ongoing studies on the technical feasibility of underground disposal (namely the OPLA studies) (VROM, 1987, p.2). It stated that criteria with regard to radiation exposure should be chosen (VROM, 1987, p.4) and long term (technical and societal) uncertainty should be taken into consideration (Ibidem, p.5). The Baseline note also provided a list of general lines of reasoning, that seem to go against R&R (Ibidem, p.3-4, own translation):

- "the protection of humans and environment should be equal for current and future generations;
- the risk of GD for humans and environment must be acceptable (…);
- future generations have limited opportunities to intervene in a closed GD;
- future generations cannot and should not have to take special measures;
- GD should not influence the choice where future generations want to live."

In 1990 the discussion of the Baseline note is abandoned. It received mostly negative reactions throughout the public consultation, because of its poor readability, but also because it is written in an ahistorical manner, without any reference to the geological and geo-hydrological insights of previous research (Laka, s.d.; Damveld, 2001).

In line with the National Environmental Policy Plan, the Baseline note discussion is replaced by a broadened debate, beyond RWM. The question is no longer related to the conditions under which

[33] Basisnotitie ten behoeve van de ontwikkeling van een toetsingscriterium voor de ondergrondse opberging van radioactief afval

GD of RW is justifiable, but whether the deep underground in principle can and should be used for disposal of non-processable waste (nuclear and chemical).

Four organisations representing different interest groups are consulted (the electricity sector, the chemical industry, the environmental movement, and environmental researchers) and an advertisement is published in the media (Alders, 1993, p.2). Following this discussion, in 1993 the Minister of Environment at the time formulates the Cabinet position on geological disposal for highly toxic waste (idem). This policy directive states that the main point of departure of environmental policy is sustainable development, among others developed through the notion of life cycle analysis with regard to waste: prevention – reuse – recycling – disposal (ibidem, p.4). In line with life cycle analysis, the production of highly toxic waste that requires disposal should in the first place be prevented. Secondly, such waste ought to be reused as much as possible and thirdly techniques such as P&T for RW should be started or continued (ibidem, p.6). Nevertheless it is stated that highly toxic waste results from the production of substances that are an essential part of products aimed at the increase of health, safety and prosperity. Therefore, since such waste has been produced in the past (ibidem, p.5) and full prevention is currently impossible, isolation is necessary and GD justified, as long as the first three principles of a life cycle approach remain inadequate.

Some important reservations are made however. Firstly, the directive resumes the part of the Note Radioactive Waste described earlier, as it states that with regard to the last resort of disposal, all three of the IBC-criteria as stipulated in the Note Radioactive Waste of 1984 should be met for the full length of disposal, i.e. not only isolation but also management and control (idem). But whereas the Note Radioactive Waste spoke about retrievability 'during the operational phase of the disposal' (VROM, 1984, p.9), the policy directive of 1993 speaks of *permanent* retrievability. It was the position of the Cabinet in 1993 that retrievability allows maximum convergence with the IBC criteria and the advantages this entails, outbalance the disadvantage of the duty of maintenance for future generations (idem). Disposal should thus not be passive, permanent and final, but, on the contrary, the disposal process should be reversible and the waste should be permanently retrievable (ibidem, p.7). Although Damveld claims it is not clear where this demand for permanent R&R exactly came from (Damveld, 2001, p.13), the governmental note is very clear: "… in this cabinet position we do not opt for really final disposal" (Alders, 1993, p.7, own translation).

This conclusion is clearly at odds with both the earlier described policy prior to 1993 (cf. for instance the third and fourth justification criteria of the list of 1987 at the previous page) and the research before 1993, which had focussed on final disposal and allowed no compromise between safety and retrievability. Moreover it follows from this demand for R&R that parts of the research of OPLA, "because of the natural closing characteristics of rock salt", is rejected (idem). Assumedly the Minister refers only to the method of disposal of LILW salt cavities here, and not to rock salt as a host geology in general, but this is not explicitly mentioned throughout the directive. This causes confusion among the public, most notably in regions that were earlier considered to have suitable rock salt geologies (Damveld, 2001; Laka, s.d.). The directive only specifies that future "… generic research shall have to be conducted on disposal methods that comply with the condition of retrievability (during the whole of the disposal period) and the reversibility of the disposal process" (Alders, 1993, p.8).

Following this demand, OPLA is abandoned and replaced by the 'Commission Disposal RW' (CORA) in 1995. CORA is aimed to coordinate a research programme focussing on the technical feasibility of retrievable disposal. Research is carried out between 1996 and 2001 and focussed on three options: retrievable underground disposal in rock-salt formations (in collaboration with Germany), retrievable underground disposal in deep clay deposits (in collaboration with Belgium), and prolonged surface storage. For each case, both retrievability and safety were investigated.

4.2 Reasons for long term retrievability

The three main reasons of the Cabinet to opt for long term retrievability were (Alders, 1993, p.7):

- the possibility of intervention;
- the possibility of re-destination;
- the possibility of relocation

The possibility of intervention is seen as an additional safety measure in light of the IBC criteria: "In regular situations, underground disposal is relatively safe due to natural isolation. However, in exceptional or unforeseen situations natural isolation may fail and the impossibility of intervening becomes, on the contrary, a large disadvantage" (Ibidem, p.6, own translation).

As it was its mission, the research report of CORA elaborates upon these in our opinion socio-technical arguments made by the government, by distinguishing possible reasons for both long term availability of and easy accessibility to the RW (CORA, 2001b, p.3; CORA, 2001a, p.22, p.95):

Resulting from retrievability:

- Future transmutation of the waste would be possible if techniques that are currently being developed permit – partial – deactivation at some time in the future.
- The waste remains available for reuse / recycling.
- The waste can be removed in case of undesirable events.

Resulting from accessibility:

- Accessibility enables monitoring and thus verification, knowledge development, evaluation and second opinions.
- Technical improvements can be made as new know-how and expertise become available.
- Information can be disseminated widely by means of (underground) visits during a demonstration phase and by media coverage.

The CORA report however also frankly displays another reason for R&R, namely the negative socio-political context surrounding permanent disposal (CORA, 2001b, p.3):

- “The Dutch policy of assured access to any storage or disposal facility to guarantee retrievability resolves many objections amongst the public. Most of these objections are summarised in the traditional saying: ‘seeing is believing’.”

Apart from the government directive from 1993 itself, almost all other documents indeed mention that the idea of R&R originally emerged mainly as what could be described as a **political softener for the public** and a **political escape for the government**. The following collection of citations from official documents illustrates this well:

> “Currently there is so much resistance against GD of RW in our country that this solution is currently not attainable. The government therefore recently decided that underground disposal of radioactive material should in any case not be irreversible” (Andriessen et al., 1993, p.47, own translation).
>
> “The government admits that the demand of retrievability burdens future generations with the care of high toxic waste. The societal resistance against the GD of RA in rock salt played an important role in the formulation of this government position” (Oosterheert, 1993, p.5, own translation).
>
> “In a retrievable situation no irrevocable decisions need to be taken, only stepwise progress decisions. (…) With retrievability the societal dialogue about waste can take a constructive turn, through which not only trust in acceptable technical solutions for the RW can be achieved, but above all consensus with regard to the process that can be followed to reach them” (CORA, 2001a, p.7, own translation).
>
> “The fact that with retrievability irrevocable decisions are avoided and the options of control, surveillance and alternative solutions remain open, is likely to diminish the resistance towards disposal” (CORA 2001a, p.13, own translation).

The following sentence illustrates the socio-technical nature of the R&R particularly well: “It can thus be seen as a means towards a participatory dialogue about both technical and societal aspects” (idem).

In the framework of the ethical study included in the CORA research (cf. infra, section 5), a questionnaire was circulated among environmental organisations. The results indicated that retrievability was mainly seen as a manoeuvre of the government to make GD acceptable and continue with the production of nuclear energy, especially because something like ‘permanent retrievability’ can never be guaranteed (CORA, 2001a, p.84 - 85). On the other hand, because of the same lack of trust in long term predictability, environmental movements are proponents of R&R (referring for instance to the unforeseen troubles with the Asse salt mine in Germany). Because, as also indicate by the CORA study (CORA, 2001a, p.14), R&R is best compatible with surface storage, preference is given to this option. At the same time the enormous complexity of the inherent condition of passing information to future generations is also realized (interview WISE, 2011). The more general challenging question of finding a balance between passing a burden and enabling the freedom of future generations is also recognized by other actors (interview COVRA, 2011, interview Ministry, 2011).

4.3 Reasons for limited retrievability

Although CORA, as pointed out in the previous section, mentions some advantages, it also highlights disadvantages of R&R, namely (CORA 2001a, p.7, p.9, p.23):

- It requires technical arrangements that make the construction and operation of the disposal more complex;
- It requires a long-term technical and organisational effort involving maintenance, data management, monitoring and supervision, which causes future generations to be burdened with the care for RW for a considerable time;
- It entails additional costs;
- It involves a greater risk of exposure to radiation.

Although the policy directive of the government required that firstly all waste should be retrievable and that secondly retrievability should be permanent, the CORA researchers did not seem to agree with these demands. Only high level waste was investigated (CORA, 2001a, p.24, p.27) and the report clearly states that “Based on today’s knowledge retrievability can only be guaranteed for a few hundred years” (CORA, 2001b, p.8). The Commission thus defined retrievability in connection to a certain period (“a couple of hundred years” (CORA, 2001a, p.22, own translation)) “during or at the end of which it can be decided to fully or partly retrieve the waste or to dispose of it definitively” (ibidem, p.78, own translation). The exact duration depends on the aim of keeping the disposal open: if the aim is reuse, economic factors will determine the duration, if the aim is transmutation, the availability of the technique will be decisive (ibidem, p.23).
In fact, the whole CORA report shows a rather critical appreciation of R&R, as it “can be seen as a delay of a passively safe end situation” (ibidem, p.9, own translation). In conclusion CORA defends (Ibidem, p.95, own translation):

- flexibility through stepwise decision making;
- a decision moment for definitive closure, in order to reach a passively safe end situation.

Actors today generally seem to agree with this final conclusion of CORA, which in fact means that R&R should not be contradictory to the principal idea of final, passive disposal.
Other lines of reasoning that reveal the socio-technical character of R&R and at the same time seem to limit the favourability of the formal uptake of the principle are the following:

- In fact any controlled process is reversible: as long as you do not destroy the waste and you know where it is, you can get it back (interview EPZ, 2011);
- We should not systematically burden future generations because it is not up to us to judge what they are capable of in the first place (idem);

- R&R may not serve as a loophole, in case the disposal does not turn out to be as safe as you would have expected. If this is the case, the disposal should not be licensed in the first place (interview Ministry, 2011).

As mentioned before, the environmental movement completely agrees with the latter argumentation, but for them this is precisely why, in light of scientific and societal uncertainty, R&R is a much needed safety principle (cf. supra).
In any case, the fact that R&R remains a legally binding yet ill-defined principle in the Netherlands is judged to hinder the debate by the majority of stakeholders (e.g. interview COVRA, interview EPZ, interview Ministry, 2011), which is why its further determination is taken up in the new research programme, OPERA (OPERA, 2011b, p.17).

5 Bridging social & technical aspects?

Throughout the introduction (section 1.5) we already expressed the idea that the Dutch case shows cognizance of the complex interaction between technical and social challenges related to RWM, but does not seem to succeed in integrating them as to reflect the socio-technical character of RWM throughout actual policy and research. We elaborated upon the cases of prolonged interim storage, regional repositories and R&R to substantiate this point of view. We will now end by zooming in more specifically on the 'separation' of 'social' and 'technical' aspects at the science-policy interface throughout the evolution of RWM in the Netherlands.

Throughout section 3.1 we pointed out that **OPLA** (1985 – 1989), due to the previously developed taboo on siting, was set up as a generic, technical-scientific feasibility study to determine the preferred disposal method in rock salt, with in fact as limited reference as possible to the real world environment in which it was to be implemented. This was not only illustrated throughout the rejection of all initially proposed site specific research, but also throughout the advice ILONA defined based on the OPLA studies, basically recommending to keep RWM outside the socio-political sphere: "No content based government position needs to be taken. (…) The report is sent to parliament only for its information" (ILONA, 1989, p.1, own translation). Throughout section 4.1 we nevertheless indicated that it was realized that societal concerns needed to be taken into account during the period of OPLA. OPLA solely applied a scientific, quantitative dose limit related to decease risk in this regard. Because of the inadequacy of this means to address societal concerns, the minister at the time prepared the 'Baseline note in behalf of the development of a test criterion for the underground disposal of RW' in 1987. We pointed out that this test criterion was deliberately developed independently of the ongoing technical studies, namely OPLA (VROM, 1987, p.2), and mentioned that at the same time this was one of the reasons why it was abandoned (cf. p.21).

Nevertheless, the same isolated treatment of 'social' and 'technical' aspects is maintained throughout the succeeding research programme, coordinated by **CORA**. As outlined throughout the previous section on R&R, CORA's aim was also to investigate the technical feasibility of this time

retrievable RWM. Nevertheless it was realized that "Even though the assignment of the Commission had a technical-scientific emphasis, disregarding the objections of society against various storage or disposal options, would not be very realistic. This prompted the Commission to include potential acceptance by society as a boundary condition in its studies" (CORA, 2001b, p.2). "In view of the public awareness of the waste-disposal issue" (CORA, 2001b, p.4), two separate studies of societal and ethical aspects were added: a survey on public participation, decision-making and discussions in eight countries (van den Berg et al., 2000), and a study focussing on ethics, sustainable development, risk perception and retrievability (Damveld et al., 2000). The main message of the latter report is that retrievable surface storage is the most ethical option, but the long term character of RWM poses dilemmas for which no real solution is available (Damveld et al., 2000, p.35). One of the recommendations is "to develop a proposal about how to interweave the technical research with societal and ethical aspects in a tighter manner" (Ibidem, p.37).
Although the final CORA summary indeed states that "An acceptable solution for the waste problem will eventually only be achieved if, in a public debate, the societal and technical aspects are considered on an equivalent basis" (CORA, 2001b, p.10), a dichotomy seems to be upheld between technical research on the one and societal debate on the other hand. The advice the ILONA Commission formulates based on the CORA report makes this clear. "In the opinion of the Commission ILONA, societal research should remain limited to scoping the potential steps relevant to decision making. It should be avoided that preparations are made for a geological disposal" (summarized in van Geel, 2002, p.10, own translation). The government, following the ILONA Commission, advices a larger role for COVRA with regard to the coordination of future research. This would shift the centre of research coordination from the government towards the implementer, a shift that "emphasizes the techno-scientific character of the research, in a phase where political choices will remain out of question" (van Geel, 2002, p.14, own translation). Consequently the ILONA Commission was abolished (interview COVRA, 2011). What seems to be retained mostly from the ethical and societal research is the apparent coupling between RW and a negative attitude toward nuclear energy, and the consequent idea that deep geological disposal will lead to its continuation (CORA 2001a, p.15, van Geel, 2002, p.9). The recent application for a second reactor (cf. Delta N.V., 2009) does not ease this troublesome relation between RW policy and (nuclear) energy policy. For the environmental movement this application has a pernicious influence on the RWM debate, since the continuation, let alone expansion of nuclear energy production is judged to fundamentally impede any sincere debate about RWM (interview WISE, 2011).

At the previously mentioned **NORA** workshop in 2008, the interwoveness between technical and societal aspects is explicitly mentioned: "Because researchers in both subdomains speak a clearly different language, 'translation' of knowledge and know-how, possibilities and impossibilities to the other subdomain requires special attention" (Poley et al., 2008, p.3). Moreover, the ambiguity of the message of the previous research programmes is pointed out: on the one hand they all state that geological disposal is feasible and safe, on the other hand they all equally emphasize that further research is needed (Poley et al., 2008, p.5). The need for demonstration is stressed in this regard, but commented by a remark that it is better to speak of large-scale experiments than of demonstration (idem). With regard to prolonged interim storage, participants also acknowledge the socio-technical challenge of knowledge transfer (Poley et al., 2008, p.1). Nevertheless, the end result of the workshop is once again a proposal for a new research programme with 2 separate lines.

In 2009 the successor of CORA was initiated: the Research Programme on the final disposal of RW, **OPERA**. The aim of this new research programme, which will run between 2011 and 2016, is the evaluation of the existing RWM research and the further elimination of conceptual uncertainties with regard to safety, in a framework of international cooperation. For the study of disposal in salt the concept that was developed in the previous research programme CORA will be used. Focus will this time be on the geological formation of Boom clay, for which intense cooperation with Belgium is hoped for. Although this once again sounds like a very technical set up, an awareness of the socio-technical character of the proposed research is noticeable throughout the call for research proposals. “Research is necessary to reduce existing uncertainties, to actualize cost estimates for financial assurances with regard to the costs of the final disposal, to preserve the necessary knowledge and know-how in the Netherlands, as well as to be prepared for a location selection process in case of potential changes with regard to the urgency of final disposal” (OPERA, 2011a, p.2, own translation). It is realized that the notion of ‘safety’ needs to be elaborated beyond a solely quantitative assessment of risks (interview COVRA, 2011). The research programme is also overlooked by a multidisciplinary advisory board (Idem).

Nevertheless, OPERA quite literally duplicates the governmental advice of 2002 based on the preceding CORA study, to limit societal research to scoping the potential steps and participants to such a process, and to avoid the impression of making preparations for an actual geological disposal. The potential shift to clay instead of rock salt in fact enables this more easily in what can be seen as a socio-technical manner: “It should be noted that due to the Dutch policy of long-term interim storage no pressing need exists to realize a repository in the near future. In the current management strategy (…), siting is not foreseen in this century. Furthermore, due to the large abundance of Boom Clay in the Netherlands, siting is not a critical issue” (OPERA, 2011b, section II, p.5). Moreover, “It is expected that within the next decade the first radioactive waste repository for HLW will be realized in Europe, which may influence the public perception” (Idem).

The following phrase in the long-range plan of OPERA can be read as a strikingly illustrative summary of the ambiguous Dutch attitude towards the complexity of the socio-technical character of RWM:

“A clear division between contextual and technical aspects of the Safety Case allows to explicitly define the relation between societal and technical aspects” (OPERA, 2011a, p.8).

List of Abbreviations

BMD	: Broad Societal Discussion (Brede Maatschappelijke Discussie. Official name: Maatschappelijke Discussie Energiebeleid)
CORA	: Commission Disposal RW (Commissie Opberging Radioactief Afval)
GD	: Geological Disposal
HLW	: High Level Waste
IBC criteria	: Isolation – Management – Control (Isoleren – Beheersen – Controleren)
ICK	: Interdepartmental Commission for Nuclear Energy (Interdepartementale Commissie voor Kernenergie)
ILONA	: Commission Integral National Research Nuclear Waste (Commissie Integraal Landelijk Onderzoek Nucleair Afval)
LILW	: Low and Intermediate Level Waste
NPP	: Nuclear Power Plant
OECD NEA	: Organisation for Economic Cooperation and Development Nuclear Energy Agency
OPERA	: Research Programme Final Disposal RW (OnderzoeksProgramma Eindberging Radioactief Afval)
OPLA	: Storage on Land programme (Opslag te Land)
P&T	: Partitioning & Transmutation
R&R	: Retrievability & Reversibility
RW(M)	: Radioactive Waste (Management)
WRK	: Scientific Council for Nuclear Energy (Wetenschappelijke Raad voor de Kernenergie)

References

Official, national science-policy documents

Alders, J. (1993). *Kabinetsstandpunt inzake Opbergen van afval in de diepe ondergrond*. Tweede Kamer, vergaderjaar 1992-1993, 23 163, nr. 1. Available in Dutch from www.kernenergieinnederland.nl/files/19930514-tor_0.pdf (Accessed 12/12/11).

Andriessen, Alders, Vries, Kooijmans (1993). *Dossier Kernenergie*. Published by the Minister for Housing, Spatial Planning and the Environment, Minister for Economic Affairs, Minister for Social Affairs and Employment and Minister for Foreign Affairs. Summary available in Dutch from: http://www.kernenergieinnederland.nl/files/19931115-nota.pdf (Accessed 12/12/11).

CORA (2001a). "*Terugneembare berging, een begaanbaar pad? Onderzoek naar de mogelijkheden van terugneembare berging van radioactief afval in Nederland*" (February 2001). CORA end report. Ministerie van Economische Zaken - Den Haag.

CORA (2001b). *Retrievable disposal of radioactive waste in the Netherlands*. Summary. Ministry of Economic Affairs – The Hague.

Damveld, H. & van den Berg, R.J. (2000). *Nuclear Waste and Nuclear Ethics. Social and ethical aspects of the retrievable storage of nuclear waste*. CORA 20. Report in outlines available from: http://www.laka.org/info/publicaties/afval/1-verkort-engels/ingang-metra1-verkort.html (Accessed 12/12/11).

de Brauw, M.L. / Stuurgroep *Maatschappelijke Discussie Energiebeleid* (1984). Nieuwsbrief nummer 15. Available in Dutch from www.kernenergieinnederland.nl/files/19840123-conclusies.pdf (Accessed 12/12/11).

ILONA (1989). *ILONA advies en OPLA rapport inzake onderzoek opberging radioactief afval* (15 June 1989). Available in Dutch from http://www.kernenergieinnederland.nl/files/19890615-ilona.pdf (Accessed 12/12/11).

OPERA (2011a). *OPERA Meerjarenplan*. Ewoud Verhoef. COVRA NV. Available in Dutch from http://www.covra.nl/infocentrum/opera (Accessed 12/12/11).

OPERA (2011b). *OPERA Research Plan*. Ewoud Verhoef (COVRA), Thomas Schröder (NRG). Available from http://www.covra.nl/infocentrum/opera (Accessed 12/12/11).

OPERA (2011c). *OPERA First call for proposals*. Ewoud Verhoef, Erika Neeft. COVRA NV. Available from http://www.covra.nl/infocentrum/opera (Accessed 12/12/11).

OPERA (2011d). *Outline of a disposal concept in clay.* Ewoud Verhoef, Erika Neeft (COVRA N.V.) and Jacques Grupa, Arjen Poley (NRG). Available from http://www.covra.nl/infocentrum/opera ((Accessed 12/12/11).

OPLA (1989). Eindrapport fase 1: "*Onderzoek naar geologische opberging van radioactief afval in Nederland*". Summary available in Dutch from http://www.kernenergieinnederland.nl/files/19890615-opla.pdf (Accessed 12/12/11).

ter Beek, A.L., Rappa-Velt, H. (2001). *Brief aan de Statencommissie Milieu, Water en Groen inzake Rapport Terugneembare berging, een begaanbaar pad? van de Commissie Opberging Radioactief Afval*. Provincie Drenthe.

van den Berg, R.J. & Damveld, H. (2000). *Discussions on Nuclear Waste. A Survey on Public Participation, Decision-Making and Discussions in Eight Countries*. CORA 21. Available from http://www.laka.org/publicaties.html (Accessed 12/12/11).

van Geel, P. (2002). *Governmental advice following the CORA report "Terugneembare berging, een begaanbaar pad?"* Tweede Kamer, vergaderjaar 2002 – 2003, 28 674, nr.1. Available in Dutch from https://zoek.officielebekendmakingen.nl/kst-28674-1.pdf (Accessed 12/12/11).

van Geel, P. (2004). *Letter from the State Secretary for Environment and Infrastructure to the parliament concerning, among others, the reprocessing of radioactive material*. Tweede Kamer, vergaderjaar 2003 – 2004, 25 422, nr. 37. Available in Dutch from https://zoek.officielebekendmakingen.nl/kst-25422-37.pdf (Accessed 12/12/11).

Verhagen M.J.M. (2011). *Randvoorwaarden voor de bouw van nieuwe kerncentrales* (11 februari 2011). Available in Dutch from: http://www.rijksoverheid.nl/onderwerpen/kernenergie/documenten-en-publicaties/kamerstukken/2011/02/11/randvoorwaarden-voor-de-bouw-van-nieuwe-kerncentrales.html (Accessed 12/12/11).

VROM (1984). *Nota Radioactief afval*. Tweede Kamer, vergaderjaar 1983-1984, 18343, nrs. 1-2. Available in Dutch from www.kernenergieinnederland.nl/files/19890615-ilona.pdf (Accessed 12/12/11).

VROM (1987). *Basisnotitie ten behoeve van de ontwikkeling van een toetsingscriterium voor de ondergrondse opberging van radioactief afval – samenvatting*. Available in Dutch from www.kernenergieinnederland.nl/files/19870915-tor.pdf (Accessed 12/12/11).

Others

Antonisse, R (1987). De valse start van COVRA. Published in the regional newspaper *PZC* on 11/02/87. Available in Dutch from http://www.kernenergieinnederland.nl/files/19870211-openheid.pdf (Accessed 12/12/11).

Berner, B., Drottz Sjöberg, B-M, Holm, E. (2001). *Social Science Research 2004 – 2010. Themes, results and reflections*. Swedish Nuclear Fuel and Waste Management Company. CM Grubben AB, Sweden.

COVRA (1986). Persbericht: *COVRA kiest Borssele*. Available in Dutch from: http://www.kernenergieinnederland.nl/files/19860618-covra.pdf (Accessed 12/12/11).

Damveld, H.(2001). *Touwtrekken om kernafval. 25 jaar plannen maken voor opslag in zoutkoepels*. Vijf Linden, Groningen.

Delta N.V. (2009). *Startnotitie milieueffectrapport tweede kerncentrale Borssele*. Delta Afdeling Communicatie, Middelburg.

ERDO (s.d.). *ERDO Working Group information leaflet*. Available from http://www.erdo-wg.eu/Documents.html (Accessed 12/12/11).

Wright, J.K. (1981). Evaluation of the Community's indirect action programme on management and storage of radioactive waste. *Nuclear science and technology* Number 4 of Research evaluation report.

European Commission (1982). *Research and Development on radioactive waste management and storage.* Second Annual Progress Report of the European Community Programme 1980 – 1984. Radioactive Waste Management – A Series of Monographs and Tracts, Volume 8. ECSC, EEC, EAEC, Brussels and Luxemburg. Harwood Academic Publishers, Switzerland.

Hagendijk, R. and Terpstra, A (2004). *Technology, risk and democracy: The Dutch nuclear energy debate (1981 – 1984)*. Discussion Paper 14 of STAGE (Science, Technology and Governance in Europe), a EC FP5 thematic network. Available from: http://www.kernenergieinnederland.nl/files/19840123-conclusies.pdf (Accessed 12/12/11).

IAEA (1983). *Concepts and Examples of Safety analyses for radioactive waste repositories in Continental geological formations*. IAEA Safety Series no. 58 (procedures and data) IAEA STI/Pub/632, IAEA, Austria.

IAEA (2004). *Developing multinational radioactive waste repositories: infrastructural framework and scenarios of cooperation*. IAEA-TECDOC-1413, IAEA, Austria.

KFD (2008). *Veertig jaar nucleair toezicht*. VROM – Inspectie, Den Haag.

Laka (ongoing). *Kernenergie in Nederland*. Website describing the history of nuclear energy in the Netherlands. Set up and maintained by Laka, Documentatie en onderzoekscentrum kernenergie (www.laka.org). Available in Dutch from www.kernenergieinnederland.nl (Accessed 12/12/11).

Latour, B. (2004). *Politics of Nature: How to Bring the Sciences into Democracy.* Harvard University Press, USA.

OECD NEA (1982a). *Geological disposal of radioactive waste; research in the OECD area*. OECD, Paris.

OECD NEA (1982b). *Disposal of radioactive waste; an overview of the principles involved*. OECD, Paris.

OECD NEA (1987). *International Approaches to the Use of Radioactive Waste Disposal Facilities, A Preliminary Study*. OECD, Paris.

OECD (2009). *Nuclear Legislation in OECD countries – The Netherlands*. Available from www.oecd-nea.org/law/legislation/netherlands.pdf (Accessed 12/12/11).

Oosterheert, R.J (1993). Dossier Kernenergie – tweede hoofdstuk 'Focus' in het *Energie Verslag Nederland 1993*. Energieonderzoek Centrum Nederland (ECN).

Poley, A & Verhoef, E. Verslag van de NORA workshop – *Opberging radioactief afval – Van internationale samenwerking tot een gezamenlijk onderzoeksprogramma*. COVRA, Vlissingen & NRG, Petten, 2008.

van der Zwaan, B. (2008). Nuclear waste repository case studies: The Netherlands. *Bulletin of the Atomic Scientists*, The Bulletin's web-edition of 19 May 2008. Available from http://www.thebulletin.org/web-edition/reports/nuclear-waste-repository-case-studies/nuclear-waste-repository-case-studies-the- (Accessed 12/12/11).

van Vugt, F (2004). *De hardheid van de nucleaire optie in Nederland. Een onderzoek naar de teloorgang van een verguisde technologie*. Afstudeerscriptie, Energiecentrum Nederland beleidsstudies, ECN-I--04-001.

World Nuclear Association (s.d.). National policies – Radioactive Waste Management – Appendix 3. Available from http://www.world-nuclear.org/info/inf04ap3.html (Accessed 12/12/11).

Interviews

- COVRA (implementer)
  Ewoud Verhoef, Erika Neeft, 14/07/11, Borssele

- EPZ (producer)
  Jan Wieman, 05/08/11, Borssele
- Ministry of Economy, Agriculture and Innovation
  Hedwig Sleiderink and Aad Sedee, 31/08/11, Den Haag
- WISE (NGO)
  Peer de Rijk, 24/08/11, Amsterdam

Annex 1

Overview of the estimated inventory and disposal dimensions (OPERA, 2011d, Appendix, p.1):

Table A-1 Expected inventory of LILW intended for disposal

Container Type at storage	Waste classification [1]	Dimensions [m] [2]	Number of containers	Max Dose rate [mSv/h]	Max. weight [kg]	Container material
200l	A/B/C/D	0.59 × 0.88	140,000	10	1,900	Galvanized steel/ concrete container
600l		0.85 × 1.23	180			
1000l		1.00 × 1.25	12,000			
1500l		1.00 × 1.90	280			

[1] Category A is waste contains alpha emitting radionuclides | Category B is contaminated waste from the nuclear power plants Borssele and Dodewaard | Category C is waste contaminated with solely beta and gamma emitters with a half life longer than 15 years | Category D is waste contaminated with solely beta and gamma emitters with a half life shorter than 15 years. This classification can be found in the Joint Convention report [1] For the purpose of this study it is assumed all LILW is intended for geological disposal even though some of the waste will have decayed below exemption levels after 100 years of interim storage.
[2] diameter × length of package suitable for disposal

Table A-2 Expected inventory of (TE)NORM intended for disposal

Container Type at storage	Waste classification	Dimensions [m] [1]	Number of containers	Max Dose rate [mSv/h]	Max weight [kg]	Container material
KONRAD Type II	Depleted uranium (U_3O_8)	1,7 * 1,7 * 1,6	18,000	10	10,000	Concrete

[1] Height × length x width of package suitable for disposal

Table A-3 Expected inventory of HLW intended for disposal

Container type at storage	Waste classification	Dimensions [m]	Number of containers	Dose rate [Gy/h]	Weight [kg]	Container material
ECN	Spent fuel, uranium filters	0.74×0.95	150	60	≤1,000	Stainless steel type 304
CSD-V	Vitrified waste	0.43×1.34	625	600	500	Stainless steel type 316
CSD-C	Compacted hulls and ends	0.43×1.34	1,250	10	≤850	Stainless steel type 316
Not yet specified	Other non-heat-generating HLW	0.74×0.95	2,000	10	≤1,000	Stainless steel type 304

ECN = container designedby Energieonderzoek Centrum Nederland | CSD-V= Colis Standard de Déchets – Vitrified ; containers designedby the French company COGEMA (CompagnieGénérale des MatièresNucléaires) as well as glass matrix, presently AREVA | CSD-C= Colis Standard de Déchets – Compactés ; containers designedby the French company COGEMA (CompagnieGénérale des MatièresNucléaires)

Table A-4 Dimensions of the shafts, galleries and tunnels

	Number	Length [m]	Diameter [1] [m]	Concrete Support Thickness [m]	Gallery Spacing [m]
Shaft	2	500	6.2/5.0	0.60	1110
Main Gallery	1	7200	4.8/3.7	0.55	N.A.
Secondary Galleries	6	1100	4.8/3.7	0.55	280
Disposal Tunnels					
Heat-generating HLW	47	45	3.2/2.2	0.50	50
Spent fuel	6	45	3.2/2.2	0.50	50
Non-heat-generating HLW	21	200	3.2/2.2	0.50	50
LILW and DU	103	200	4.8/3.7	0.55	50

[1] Excavated diameter/inner diameter of the gallery support

Annex 2

A preliminary, artist impression of what a future geological disposal concept in Boom Clay may look like (OPERA, 2011d, p.10):

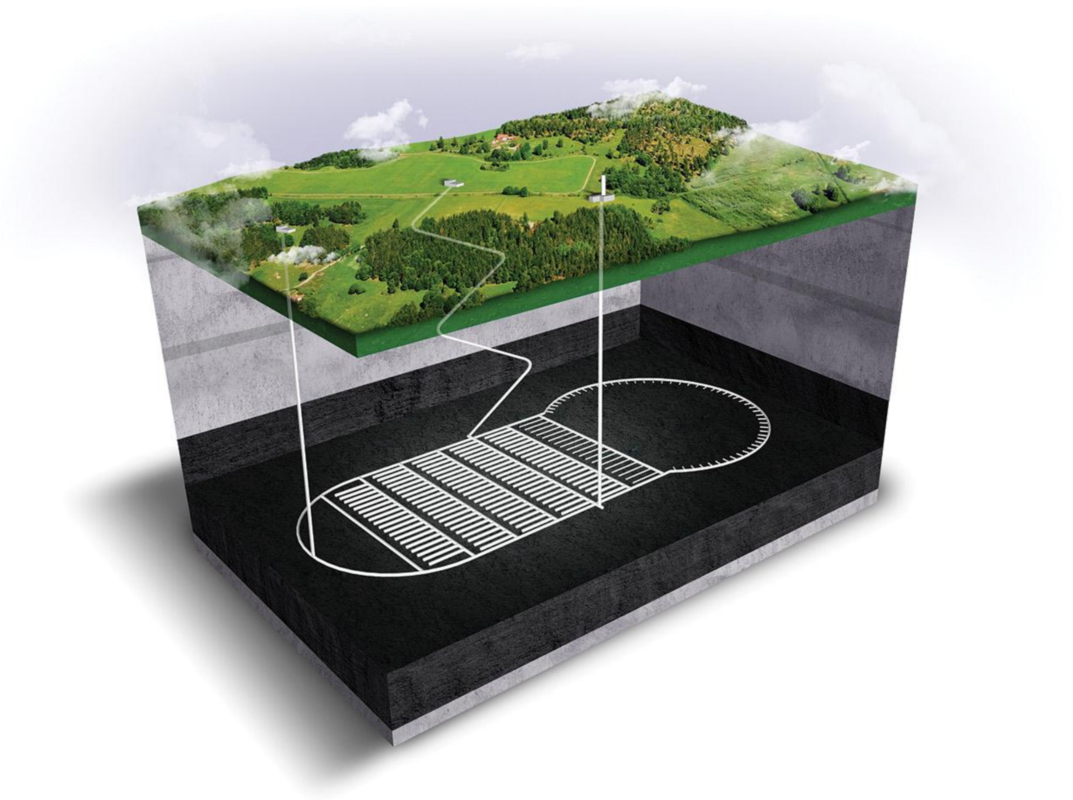

Figure 1: Artist impression of a geological repository for the disposal of radioactive waste in Boom Clay