EUROPEAN COMMISSION

Community research

inSOTEC

WORKING PAPER

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

(WP 1 – MS 3)

Authors: Jantine Schröder & Anne Bergmans (UA)

Date of issue: **10/05/2012**

EURATOM

This report is issued by:

ISBN: 978-90-5728-385-7

Contents

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 Belgium.
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 explore the notion on a more general level throughout an introductory chapter (section 1) and subsequently on a more dedicated level by means of a description of the in our opinion prevailing socio-technical challenges for the Belgian case (section 2). The identification of prevailing socio-technical challenges in Belgium is based on a review of relevant literature and publications, the revision of research programs, the experience of the authors of this report gained through different research activities and projects, and the exchange with key actors through interviews. With regard to the latter, in order to consider a broad spectrum of views on socio-technical challenges in Belgian radioactive waste management activities, five interviews have been conducted, with representatives of the implementer, the Belgian nuclear research centre, the regulator, an NGO and the Federal Administration of Economy and Energy.
We gratefully acknowledge all the people who collaborated in this work, through interviews, responding to questions in e-mails and sending research material.

1 General introduction to the Belgian nuclear context

1.1 Nuclear capacity

Due to historical events, notably the presence of uranium in the former colony of Congo, Belgium developed a rather extensive nuclear programme early onwards, with once the ambition to nationally cover the full nuclear fuel cycle.[1] In 1952 a national nuclear research institute was founded, which would later become the Belgian Nuclear Research Centre (SCK•CEN), located in the municipality of Mol. In subsequent years after the foundation of SCK•CEN, Mol and the neighbouring municipalities of Dessel and Geel additionally came to host a reprocessing factory, Eurochemic (closed in 1985); a MOX fuel production factory, Belgonucleaire (closed in 2006); a fuel production factory, FBFC International (an Areva subsidiary – late 2011 the decision was made to close the factory); and the Euratom Institute for Reference Materials and Measurements (IRMM). In the South, in Fleurus, the National Institute for Radioisotopes (IRE) was set up.
The decision to launch a nuclear power programme was taken during the sixties. In between 1975 and 1985 seven pressurized water reactors became operational, divided over two sites. One nuclear power plant (NPP) is located in the Northern, Flemish part of the country (in Doel, with 4 reactors), the other one is situated in the Southern, Walloon part of the country (in Tihange, with 3 reactors).

[1] For an elaborate treatment of the early history of the Belgian nuclear programme cf. Laes et al., 2007, chapter 1. A summary can be found in Bergmans et al., 2006, p.4. Although it falls beyond the scope of this report, an analysis of the socio-technical character of the historical development of the Belgian nuclear programme would undoubtedly be interesting.

Nuclear power accounts for 54% of the Belgian electricity production (World Nuclear Association, 2012).
Apart from these nuclear organisations, universities, hospitals, agriculture and several non-nuclear industries also produce radioactive waste (RW). Nuclear power clearly produces the majority of the total amount of RW (80%).[2]
Summarized, from an international perspective, Belgium can be said to be a relatively prominent nuclear actor, both with regard to nuclear infrastructure as with regard to related research.

1.2 Main legislation and regulation

Belgium is a federal state with three regions (the Flemish, Walloon and Brussels Capital Region) and three communities (the Dutch, French and German speaking Community). All issues related to the development, deployment, applications and consequences of nuclear technology and radioactivity belong to the competence of the federal, national level. The fact that other potentially connected domains, such as environmental legislation, spatial planning, employment, certain aspects of emergency management, … belong to the competence of the regional and local regulatory levels, does not always enhance transparency and practicability.

The **basic regulations for the safety of nuclear activities** was first laid down in the law of 29 March **1958** regarding the Protection of the Population against the Hazards of Ionizing Radiation, accompanied by the royal decree[3] of 28 February 1963[4]. It governed the licensing of nuclear facilities, the inspection and control regime, radiological protection, medical applications of ionizing radiation, import, transit, distribution and transport of radioactive substances, and radioactive waste management. With regard to RW, these first, dedicated legal documents merely state that every actor is responsible for the safe management of the RW it produces.
This law of 1958 was repealed and replaced by the that of 15 April 1994[5], which also constituted the legal basis for the Federal Agency for Nuclear Control (FANC / AFCN) as the Belgian nuclear regulatory body.[6] In fact the installation of both a "national regulatory agency for all nuclear activities" and of a "governmental agency for the management of radioactive waste and spent fuel" was already foreseen in 1980, in a law on budgetary proposals.[7] The **National Institution for the Management of Radioactive Waste and Enriched Fissile Materials** (NIRAS/ONDRAF) was indeed founded and its responsibilities specified by **royal decree** in **1981**.[8] The law of 1980 has been amended and elaborated by other laws various times and is in the meantime complemented by

[2] See www.nirond.be (Accessed: 17/02/12)
[3] A royal decree provides a law with the necessary measurements for its implementation.
[4] Belgisch Staatsblad (BS) (the official information journal of the Belgian State; the law gazette) 16 May, 1963, 5206.
[5] Law of April 15, 1994 regarding the protection of man and the environment against potential hazards arising from ionized radiation and regarding the Federal Agency for Nuclear Control (BS 29 July 1994, 19537).
[6] The latest revision, mainly to harmonize the law with the in the meantime finally operational FANC and with new European legislation, is the Royal Decree of 20 July 2001 regarding the Protection of the Population, the Workers and the Environment against the Hazards of Ionizing Radiation (BS 30 August 2001, 28909). This is accompanied by two other Royal Decrees related to the functioning of FANC (BS 30 August 2001, 28906 and 28907).
[7] Law of August 8, 1980 concerning budgetary proposals 1979-1980, Article 179, §2. BS, 15 August 1980. Replaced by the more detailed and elaborate Law of 11 January 1991, replacing article 179, §2 of the law of 8 August 1980 concerning the budgetary proposals 1979-1980 (BS 12 February 1991, 2797). Extended with Programme law 12 December 1997 concerning diverse regulations (BS 18 December 1997, 34132).
[8] Royal Decree of 30 March 1981 regarding the stipulation of the tasks and working modalities of the public agency for the management of radioactive waste and fissile material (BS 5 May 1981, 5651).

various new royal decrees, but it remains the basis for Belgian Radioactive Waste Management (RWM).

With regard to the future of nuclear energy in Belgium, in 2003 the Belgian Parliament adopted a **phase out law**[9], which prohibits the installation of new reactors and stipulates the closure of all reactors after a lifetime of forty years. This would mean that the first three reactors would be shut down in 2015. However, an exception clause was added, stating that the lifetime of the reactors could be extended if the country's security of electricity supply would be endangered ('force majeure'). Since it was decided, this law has been the subject of debate and controversy. On several occasions intentions have been expressed by various ministers to extend the lifetime of the existing facilities, but up until today this has not become official policy.[10] The current governmental agreement stipulates "that the 2003 nuclear phase-out law will be respected, but the exact closing date of the three oldest reactors would depend on the availability of replacement capacity" (Glorieux, 2011, p.8).

Two main **financing mechanisms** have been set in place for the long term management of radioactive wastes (Bergmans & van Steenberge, 2006, N/O, 2011a, p.61 - 66).
The first serves for the long-term management of the waste, mainly to be understood as final disposal. This Fund for the Long-Term management of all radioactive wastes (FLT) has been operational since 1999 and serves for the financing of the temporary storage and eventually the final disposal of the radioactive wastes under the ownership of NIRAS/ONDRAF (N/O). The FLT is structured as a capitalisation fund. Anyone who passes on radioactive waste to N/O needs to deposit a certain amount (based mainly on the quantity and radiological character of the waste) in the Fund.
The second mechanism provides for the future funding of the decommissioning of nuclear power plants and for the management of spent fuel. Synatom, a subsidiary company of nuclear power producer GdF Suez Electrabel, is the dedicated care-taker of these provisions.[11]
This second mechanism was introduced after the liberalization of the energy market and the phase out law.[12] Another reason why it is in place, is because the official status of spent fuel in Belgium is unclear; since 1993 there exists a moratorium (no definitive legal ban) on reprocessing[13], but no final decision has been taken. Therefore spent fuel is not officially considered waste and remains under the ownership of Synatom.
In the framework of the repository project for low and intermediate level waste heading towards the implementation phase, a third financing mechanism has recently been introduced. Whereas the FLT is dedicated to the technical aspects of final disposal, a Fund for the Middle-Term (FMT) was specifically set up to comply with "the complementary conditions" of the host community (N/O, 2011a, p.65, own translation. See also section 1.4.1). It concerns costs "to create and maintain the necessary societal support for the integration of a disposal installation in the local collectivity"

[9] Law of 31 January 2003 on the Gradual Phase-out of Nuclear Energy for the Purposes of Industrial Electricity Production (BS 28 February 2003, 9879)

[10] After the elections of 2007, for example, the new prime minister expressed plans for a ten years lifetime extension of the three oldest reactors and a twenty years extension for the four other reactors. In October 2009 the succeeding prime minister set up a draft protocol with the GdF-Suez group in which they agreed to extend the lifetime of Doel 1, Doel 2 and Tihange 1 with ten years. In exchange for the 'windfall profits' this would entail, a yearly nuclear tax and a commitment to invest in renewable energy sources were agreed upon. However, in 2010, before the proposals were passed by parliament, the government fell.

[11] http://economie.fgov.be/nl/consument/Energie/Nucleaire/kerncentrales/Ontmanteling_kerncentrales/ (Accessed: 14/03/12)

[12] Law of 11 April 2003 on the provisions for the decommissioning of the NPPs and the management of fissile material irradiated in these NPPs (BS 15 July 2003, 37954)

[13] Parliamentary Resolution of December 22, 1993 regarding the use of plutonium and uranium containing fuel in Belgian nuclear power plants and the opportunity for the reprocessing of nuclear fuel rods (Parlementaire Stukken 1991 – 1995, 0541/9 – 91/92 (B.Z.))

(Idem). The law[14] installing this new fund provides for the general principle and management structure (similar to the FLT fund), so that it can be used for all types of radioactive waste disposal facilities. For each concrete project a separate royal decree will be issued to determine how much additional provisions should go into the fund and on which basis.

With regard to public participation in RWM, the government has assigned N/O with the development of a societal process for the long term management for low and intermediate level waste in 1998[15] and for the long term management of high and / or long lived waste in 2004[16]. Current formal, federal legislation is among others based on translations of international conventions and directives (the Aarhus convention and the European Directives on Environmental Impact Assessment and Strategic Environmental Assessment).[17]

Furthermore, the Euratom directives on radiological protection and on the nuclear basic safety standards have been implemented and the International Treaties on nuclear safety and on the safe management of nuclear waste have been ratified. The licensing process for nuclear installations is amongst other criteria based on the IAEA safety fundamentals and safety series.

In 2010 FANC drafted a proposal for new legislation on the licencing procedure for definitive disposal. An adjustment of the existing licencing legislation for nuclear installations of 1994 (cf. supra) was proposed to account for the specific character of installations for final disposal, notably their long life time and the fact that they are not planned to be dismantled (interview FANC, 2011). A royal decree was drafted, but it has not yet been formally published.

Summarized, the Belgian nuclear policy and regulatory framework is spread across a variety of actors and regulatory sources.

1.3 Main actors

Belgium has a rather large diversity of public, semi-public and private nuclear actors. Throughout this section we briefly describe the in our opinion most prominent ones and their main responsibilities / activities.

The **Belgian Nuclear Research Centre SCK•CEN** is a Foundation of Public Utility under tutelage of the Federal Minister of Energy. It was founded in 1952 to promote the peaceful applications of nuclear energy. In the early days, the centre created its own 'Waste department' and gradually also started to take care of other parties' wastes with similar characteristics. But as the amount and diversity of RW expanded, notably due to the start of nuclear energy production, the functionality of the Waste department of SCK•CEN became too limited. Furthermore this activity lacked any legal basis and the need for an independent waste management organisation became apparent (Bergmans & Van Steenberge, 2006; Laes et al., 2007, p.105). After the establishment of this organisation, N/O (cf. infra), close collaboration with SCK•CEN continued, and the centre initially retained the responsibility

[14] Law of 29 December 2010 concerning diverse provisions (Titel 16, Chapter 3) (BS 31-12-2010, 83506)
[15] Decision by the Cabinet Ministers of the Federal Government of January 16, 1998
[16] Verwilgen, 2004
[17] The Law of 17 December 2002 (BS 24 April 2003, 22128), which transposes the Aarhus Convention into Belgian legislation, the Law of 5 August 2006 on public access to environmental information (BS 28 August 2006, 42538), which transposes the European Directives 2003/4/EC, the Law of 13 February 2006 on the assessment of the environmental impact of plans and programmes and on the participation of the general public in the development of plans and programmes related to the environment (BS 10 March 2006, 14491), which is a transposition of the European Directives 2001/42/EC on Strategic Environmental Assessment (SEA) and 2003/35/EC on public participation in decision making in environmental matters.

for the treatment of certain waste types. A scandal involving some SCK•CEN collaborators[18] as well as the need for additional treatment and storage facilities brought an end to the centre's waste treatment activities, which were taken over by N/O and its daughter company Belgoprocess (cf. infra) (Ibidem). Due to a combination of this scandal and international evolutions and events (e.g. Chernobyl), the general statutes of the nuclear research centre were adapted in 1991, emphasizing safety, radiation protection, non-proliferation and RWM.[19] SCK•CEN continued and continues to be the main research contributor for the research N/O commands, and also conducts research on its own initiative related to theoretical, introductory and additional issues that add to the fundamental scientific base of RWM (interview SCK, 2011; Delcroix, 1997).

The **National Agency for Radioactive Waste and Enriched Fissile Materials**, **NIRAS/ONDRAF**, carries all formal responsibility and authority with regard to both the short term as well as the long term management of all radioactive waste on Belgian territory. N/O is a public agency under the tutelage of the Federal Minister(s) responsible for Energy and Economy. It is however not financed by the State, but by private entities, through the polluter pays principle.[20] After compliance with acceptance criteria and payment by the RW producers (into the aforementioned Fund – FLT), N/O becomes owner of the RW. This ownership is not 'absolute', in the sense that if the price set by N/O and paid by the producers in a later stage of RD&D[21] turns out the be inadequate, the price of the waste to come is adjusted as to compensate for the previous deficits (interview SCK•CEN, 2011). Apart from the identification of the acceptance criteria, the responsibilities of N/O include the following activities to which these (future) acceptance criteria apply: transport, treatment, conditioning, storage and disposal of all RW in Belgium. Keeping an inventory of all nuclear installations and sites (including obsolete ones) and the radioactive substances they contain also falls under N/O's mandate.
For the execution of many of these responsibilities, N/O subcontracts third parties (e.g. Transubel for nuclear transport, Tractebel-engineering for infrastructural work, …). The same goes for research, which is performed by SCK•CEN, universities and other research institutes, private (e.g. engineering) companies, and throughout international cooperation.

All substances that have been declared as waste and of which the ownership is transferred to N/O are stored at the premises of **Belgoprocess** (BP), including the returning vitrified and compacted waste from past reprocessing contracts. The location of this interim storage followed automatically from the location of the two first large waste producers, namely the nuclear research centre SCK•CEN and the former reprocessing plant Eurochemic.[22] BP is the industrial daughter company of

[18] The 'Transnuklear scandal'. For some more information, see for instance Bergmans & Van Steenberge, 2006, p.17.
[19] Royal Decree of 16 October 1991 (BS 22 November 1991, 26088)
[20] Insofar as the State owns some of the nuclear liabilities of the past, i.e. historic waste for which the responsible parties are no longer to be traced and no provisions were made, it is also considered a polluter that has to pay its share to N/O.
[21] Research, Development and Demonstration
[22] BP's history is in fact closely affiliated with that of Eurochemic. This experimental reprocessing factory started off as an OECD project in 1957. Rather soon however, France and the UK left the project to develop their own reprocessing activities, and the factory turned out to be uncompetitive. This led to the end of the OECD project in 1975. To discuss responsibilities and the potential future of the factory, the study syndicate BP was founded. Together with the Belgian government it was decided to try and re-operationalize the plant, this time to supply domestic needs only. To this aim, BP was transferred into a private company in 1984. In the meantime however, due to technical, political and economic arguments, the international reprocessing scene had drastically changed and public resistance against reopening the plant had steadily grown. By 1985 the industrial partners united in BP did not consider reopening Eurochemic to be economically viable and the decision was taken to not restart the plant. Eventually the Belgian State took over the factory and commissioned N/O to take over all shares of BP. This is when BP was transformed into the industrial subsidiary

N/O. It is in charge of the industrial management of the processing and storage of radioactive waste, whereas N/O is responsible for the administrative management and research (FANC, 2003, p.41). BP is currently processing, conditioning and storing all categories of radioactive waste resulting from both the nuclear fuel cycle activities and from the production and uses of isotopes in medicine, agriculture and industry.[23]

Synatom (Société belge des Combustibles Nucléaires) is the private company that owns the nuclear fuel and is responsible for the management of the Belgian nuclear fuel chain, from the supply of uranium to the handling of spent fuel (SF). As mentioned before Synatom is responsible for collecting and managing the provisions for the decommissioning of the NPPs and the management of spent fuel. This task includes establishing decommissioning strategies and scenarios for SF, as well as providing cost estimations and securing and managing the actual financial provisions. Synatom is a 100% daughter of **GdF Suez Electrabel**, the power generating company which owns both NPPs in Doel and Tihange.[24]

The **Federal Agency for Nuclear Control** (FANC / AFCN) is the Belgian regulator, responsible for the protection of the population and the environment against the dangers of ionising radiation.[25] It is in charge of both the licencing of activities involving ionising radiation (including transport of radioactive material) as well as for the control of these activities. FANC defines the rules, licences the installations to which these rules apply, and controls compliance with the rules. It needs to be mentioned that with regard to the so called 'class I installations', put simply the big nuclear installations (including future waste disposal installations), FANC only makes the licencing proposal. The licence itself is granted via Royal Decree, i.e. by the federal Minister of Interior Affairs (FANC's tutelage Minister) and signed by the King. The actual inspection of compliance with the licence and the licence conditions of these installations is carried out by FANC's subsidiary, Bel V (interview FANC, 2011).

Apart from these strictly nuclear actors, quite some **environmental movements** have nuclear energy and RW rather high on their agenda (e.g. Greenpeace Belgium, Interenvironnement Wallonie).
The **local partnerships**, involving people of the municipalities of Mol and Dessel, should also be mentioned (cf. also section 1.4.1). They play a pertinent role notably with regard to the long term management of low and intermediate level, short lived waste. But they also follow up evolutions regarding high-level and / or long lived waste and nuclear issues in general, as the nuclear site of Mol-Dessel-Geel hosts a diversity of related activities (see supra).

1.4 Radioactive Waste Management

In line with the classification of IAEA, N/O differentiates between:

- low and intermediate level, short lived waste (LILW) or category A waste
- low or medium-level and long-lived waste or category B waste
- high-level short or long-lived waste or category C waste

---

of N/O it is today, its first task being the dismantling of the Eurochemic plant, and the caretaking of all its liabilities (Laes et al., 2007 and Bergmans and Van Steenberge, 2006).

[23] See www.belgoprocess.be (Accessed: 17/02/12)

[24] One other company, SPE (EdF Luminus) has a minor participation in the Belgian NPPs. Overall, since the liberalisation of the electricity market, a few new players have emerged, but up until today Electrabel (currently owned by the French company GdF Suez) remains by far the largest electricity utility and still has a de facto monopoly with regard to nuclear energy in Belgium.

[25] See www.fanc.be (Accessed: 17/02/12)

For the category A waste, surface disposal is found appropriate, for the category B & C waste, the reference solution of N/O is geological disposal.[26]

1.4.1 The long term management of cat. A waste

We briefly touch upon the Belgian management for cat. A waste, because it may entail insights with regard to the socio-technical character of RWM in general and with regard to existing and potential future management of cat. B & C waste.
After an era of dumping cat. A waste into the North Sea ended under influence of the London Convention, in the early nineties N/O decided that surface disposal was a suitable option for this type of waste.[27] Based on technical, spatial and geological considerations, over 90 municipalities were approached as potential host sites for such a surface disposal. Without exception, all refused.

> *"The report of 1994 did not pass without notice: it caused, on the contrary, a unanimously rejecting reaction from all municipalities that occurred on the list. While it had been mandated to look for a safe solution for the problem of radioactive waste in an objective and rational manner, NIRAS had, to its big surprise, stirred up a general protest. Gradually NIRAS realized that there were important parameters missing in its mathematical model. The siting of a disposal infrastructure would unavoidably be accompanied by economic, social and ecological consequences. These parameters, however, were impossible to calculate into the modelling" (N/O, 1999, own translation).*

It was thus through the issue of siting that RWM became gradually acknowledged, at least to a certain degree, as a challenge in which technical and social aspects are and should be integrated. This transition is also reflected by the fact that in 1998 the government formally elaborated N/O's mandate to design a public participation process and to restrict its search to existing nuclear sites, or other communities on a voluntary basis.[28]
In collaboration with social scientists from two Belgian universities the 'local partnership' approach was designed. This approach was set up as a long term, integrated (covering both technical feasibility and social acceptability) process of co-design (N/O together with representative local actors) to come to a collectively supported decision on acceptance or rejection.[29] In 2005, the neighbouring communities of Mol (with the partnership MONA) and Dessel (with the partnership STOLA) both expressed a willingness to host a LILW repository under certain conditions. These included the continuation of participation, the conservation of regional nuclear know-how and expertise, and the permanent monitoring of effects regarding environment, safety and health and long term control of the repository. Clear reference was also made to retrievability and reversibility (R&R) and the preservation of memory of the existence of the repository (STOLA, 2004; MONA, 2005). Since Dessel has been chosen in 2006, both STORA and MONA[30] remain to exist and participate in the further steps of the decision-making process and the actual development of the disposal project.

---

[26] See www.niras.be/engels/6.4_classificatie_eng.html (Accessed: 17/02/12)
[27] NIROND 90-01, NIROND 94-04
[28] Decision by the Cabinet Ministers of the Federal Government of January 16, 1998. This decision also included a demand for reversibility, cf. infra (section 2.3).
[29] For an elaborate treatment of the Belgian case of cat. A waste, see Bergmans, 2005, Bergmans & Van Steenberge, 2006, Laes et al. 2007, Laes et al., 2008.
[30] In 2005 STOLA ('Study and Consultation group for Low-level waste') changed its name to STORA ('Study and Consultation group for Radioactive waste'). The name MONA (Mols Deliberation Nuclear Waste Cat.A) was kept, but the original "Cat. A" got deleted in what the acronym stands for.

1.4.2 The long term management of cat. B & C waste

Research on geological disposal (GD) for cat. B & C waste started early in Belgium. Already in the seventies an inventory of potential geological formations was made. In 1974 detailed investigations started on Boom Clay, conveniently available under the nuclear research centre in Mol (SCK•CEN). In 1980 the construction of an Underground Research Laboratory (URL) in a geological clay layer commenced, the first of its kind worldwide (located 225 meter deep in the Boom clay under the SCK•CEN premises, named HADES).[31] Since 1995 HADES became a joint venture between SCK•CEN and N/O, known today as EURIDICE.[32]
Table two gives a summary of the main research phases related to the Belgian case of high level waste (HLW[33]) management, and the main accompanying policy decisions.

Table 1: Overview of the main research milestones in RWM in Belgium

SAFIR I (1989) (Safety Assessment and Feasibility Interim Report I) summarizes the work on long-lived and high level waste conducted between 1974 and 1989, namely with regard to disposal technology concepts, safety aspects and interactions with the geosphere. It aimed to offer decision makers a systematic overview and analysis of existing research results and safety evaluations. Furthermore it "proposes the most important areas for the future in which additional research ought to be conducted *in order to confirm the 'option clay'*" (Evaluation Commission SAFIR, 1990, p.1, own translation & italics). Moreover "it proposes an industrial project with regard to geological disposal of the ***irreversible*** kind and points out the possible location which, because of both scientific and technical as well as favourable societal conditions, territorial reasons and local circumstances, connected to spatial planning and the location of SCK•CEN, appears to be the ***region of Mol-Dessel***" (Evaluation Commission SAFIR, 1990, p.1, own translation & italics). The State Secretary of Energy at the time installs and asks the advice of an expert evaluation commission, which agreed with the main features of SAFIR, but also formulated some comments. Two important recommendations were the inclusion of spent fuel to the disposal concept (and not only vitrified waste from reprocessing) and a preliminary characterisation of the Ypresian clay, among other places available beneath the nuclear zone of the NPP in Doel (Ibidem, p.7).

SAFIR II (2001) summarizes the work on long lived and high level waste conducted between 1990 and 2000. The aim still was explicitly not to make a licence application, but once again to be a state-of-the-art report and to propose the main future technical orientations (N/O, 2001a, Introduction, p.9). "While the SAFIR report talks of 'definitive and irreversible disposal, the disposal process and repository design presented in SAFIR 2 carry within them many of the ***elements of retrievability***" (N/O, 2001a, chapter 12, p.2). Another point that distinguishes SAFIR II from SAFIR I is the strong underlining of the methodological character of the research (N/O, 2001a, Introduction, p. 4). Although an international evaluation committee concludes the Belgian cat. B & C disposal programme is "sufficiently advanced to address the siting issue" (OECD NEA, 2003, p. 11), N/O takes a more careful route. While temporary storage is described as unsustainable, it is also pointed out that "there is not a single argument that pleads for a rapid disposal of the high level waste, which in any case will only be practicable after a cooling period of at least fifty years" (N/ O, 2001b, p.8). The main report is accompanied by an extensive contextual report which discusses, on a theoretical level, the integration of technical and societal dimensions in the next phase of the programme (Ibidem, p.10). N/O thus asks the Federal Government to provide the framework for a 'transparent and

[31] High-Activity Disposal Experimental Site. See www.sckcen.be/nl/Ons-Onderzoek/Research-facilities/HADES-Underground-laboratory (Accessed: 17/02/12)
[32] EIG (Economic Interest Grouping) EURIDICE (European Underground Research Infrastructure for Disposal of nuclear waste In Clay Environment). See www.euridice.be/eng/00home.shtm (Accessed: 17/02/12)
[33] We use this abbreviation to refer to high level and / or long lived waste, i.e. cat. B & C waste.

legitimate decision-making process', with the ***intention to launch a dialogue*** on cat. B & C policy. In 2004, the government turns the tables and mandates N/O with exactly this task (Verwilghen, 2004).

The main aim of the **Waste Plan & Strategic Environmental Assessment (SEA) (2011)** is to obtain a 'decision in principle', to streamline further technical, social, legal and financial R&D towards implementation. It is however once again underlined that this ***decision in principle*** does not include any siting proposals. As it is prescribed, the SEA compares different options. In the Waste Plan N/O expresses a clear ***preference for geological disposal in poorly indurated clay*** (for which research has far and foremost focussed on Boom Clay). With regard to R&R, the Waste Plan states mainly that the implementation process will be developed step by step, and that "the fact that the waste is not intended to be retrieved does not necessarily mean that it is impossible to retrieve it or to carry out controls" (N/O, 2011c, p.5). The need for a decision-making process that integrates technical and societal aspects, which advances in steps, is adaptable, participative and transparent, and ensures continuity (Ibidem, p.19) is once again underlined. But apart from the instalment of an independent process 'guardian', no concrete proposals are made and, as in SAFIR II, the development of a normative framework is asked for by N/O. Similar to the government reaction to SAFIR II in 2004, a letter of the caretaker government in response to the Waste Plan recommends N/O to ***continue*** with the ***development of the "societal component"*** (N/O, 2011b).

Although GD in Boom clay has been the reference solution from the start of Belgian RWM research and dedicated research has steadily continued (cf. table 1), up until today there exists no official long term management policy for cat. B & C waste (including SF, in the anticipation it may one day become waste). In fact the recent activities in the framework of the Waste Plan and accompanying SEA represent the first time that cat. B & C waste was explicitly and deliberately put on the public agenda. In the following paragraphs we will therefore discuss in more detail the content and process of these two related documents.

The aim of the Waste Plan was (and is) to enable a governmental 'decision in principle', meaning "a general policy decision or directional decision about the long term management of high level and / or long lived waste".[34] According to N/O, reaching this 'decision in principle' is highly necessary to enable a transition from research to implementation as soon as possible, because of the following mixture of reasons (N/O, 2011c, p.6):

- "N/O is legally bound to have a general programme for the long-term management of radioactive waste;
- to focus the RD&D activities still required according to the final destination of this waste;
- to help it determine and optimize all the upstream aspects of management;
- to ensure the maintenance of expertise and know-how at national level, in particular in the fields of waste knowledge, RD&D and assessment of disposal system performances, which makes an essential contribution to safety;
- to enable it to apply the 'polluter pays' principle more concretely than today;
- to lift the current uncertainty relating to storage duration in the municipalities where this waste is currently temporarily stored;
- and to avoid shifting the management responsibility, including all associated burdens (technical, financial, decision-making, radiological, etc.), on to the future generations (intergenerational equity principle)".

[34] See www.niras-afvalplan.be (Accessed: 17/02/12)

Content

Geological disposal

The majority of actors within the nuclear field in Belgium strongly adheres to the internationally shared opinion that geological disposal is the safest option for long term high level waste management.[35] The in our view socio-technical reasoning behind this choice is explained as follows by practitioners in the field (not only in Belgium): In theory, there are three options to deal with RW (N/O, 2001a, chapter 1, p.4; interview N/O, 2011; interview SCK•CEN, 2011). A first one is to **completely recycle or destroy** the waste, which is today technically and in fact physically impossible (e.g. with regard to partitioning and transmutation) or too risky (e.g. with regard to shooting it into space). A second option is to **dilute and disperse** the waste, which has been refuted mainly on ethical grounds in the context of former LILW sea dumping practices. The third and only remaining solution then is to **concentrate and contain** the waste.
Concretizing this strategy for cat. B & C waste, the reasoning continues as follows (interview N/O, 2011; interview SCK•CEN, 2011; interview FANC, 2011): The radioactive character of HLW requires distancing it from man and its environment. The long-lived nature of cat. B & C waste requires this distance to be maintained over very long timespans, whereby "it is assumed that the geological stability of a host formation is greater than socio-political stability" (N/0, 2001a, chapter 1, p.9). Putting the pieces together, what one ends up with is final, passive deep geological disposal in a stable host formation (see also annex 2).

As it is foreseen by law, the SEA contained a comparison of various possible options for the long-term management of cat. B & C waste. "Some options were rejected straight away, as they are in violation of international treaties or conventions to which Belgium is signatory (for instance sea dumping and disposal in ice sheets), and/or the Belgian legal and regulatory framework (for instance disposal by injecting waste in liquid form in deep underground), and/or do no provide adequate safety guarantees (for instance surface disposal). The remaining options, i.e. eternal storage, GD, disposal in deep boreholes, long interim storage with a view to or awaiting 'something else', and the option consisting in continuing the current situation (status quo) were subjected to a cross-disciplinary assessment" (N/0, 2011c, p.8-9). In the end, two options were withheld: disposal in an appropriate geological formation and long interim storage (N/O, 2011c, p.9).
Whereas an actor like Greenpeace advocates prolonged interim storage (interview Greenpeace, 2011), N/O clearly expressed a preference for geological disposal in clay throughout the Waste Plan consultation procedure, more concretely "geological disposal in poorly indurated clay (Boom Clay or Ypresian Clays) in a single facility (i.e. one facility for all B & C waste and built on a single site) on Belgian territory as soon as possible" (N/0, 2011c, p.12).
While other actors may agree with the reasoning that today concentrating and containing is the only option, this does not mean they also agree with the conclusion of passive, final geological disposal being a 'good' management option, let alone a 'solution' for HLW.[36] N/O's outspoken preference for GD in Boom clay in fact received quite some critique throughout the public consultations (cf. infra) on the Waste Plan. The formulation of a 'a decision in principle' was found misleading in this regard, as some stakeholders perceived the Waste Plan as a form of 'silent decision making' towards the

[35] E.g. **EURATOM**, *Council Directive 2011/70/EURATOM of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste* (OJ L 199, 02/08/2011, p. 48–56); **OECD NEA** (2008), *Moving Forward with Geological Disposal of Radioactive Waste. A Collective Statement by the NEA Radioactive Waste Management Committee*; **Blue Ribbon Commission** on America's Nuclear Future (2012), *Report to the Secretary of Energy*.

[36] A recent national survey for instance indicated that the average Belgian citizen agrees slightly more with the description of geological disposal as an "acceptable management option" as compared to a "solution" for HLW, but overall 52% does not agree with the statement that geological disposal solves the issue of HLW and 41% does not find it an acceptable management option (Turcanu et al., 2010, p.62).

most researched option and within the timeframe N/O a priori has in mind. Also outside the public consultations, due to the strong focus on more than 30 years of research into the Boom-Clay option, the Waste Plan was interpreted by many as a hidden agenda to start siting in the Mol-Dessel area, resulting in public protests, also across the border in the south of the Netherlands. A connected critique within the consultation was that remaining uncertainties surrounding GD were underexposed, and alternative management options treated marginally in comparisons to the favoured options. Summarized, throughout various commentaries the maturity of the GD option was questioned and the continuation of research and the close follow up of evolutions with regard to alternative management options and technologies recommended (e.g. KBS 2010a, p.20; ACW/ACV, 2010; Minon, 2012). From the results of the public consultations N/O derived retrievability, control mechanisms, and transfer of knowledge as the main conditions for the implementation of long term RWM (N/O, 2011a; N/O, 2011d, p.134; Eeckhout, 2011). Debates on these topics reveal a more in depth variety of socio-technical arguments on whether or not to opt for GD and under which conditions, as we will come to show throughout section 2.

Boom clay

The choice for Boom clay as the reference host formation for GD was in made early in Belgium. As other stable geological formations such as salt or granite are not nationally available in a convenient manner, already in the seventies nuclear researchers judged poorly indurated clay most appropriate (interview FOD Economy, 2011; Laes et al., 2007, p.150). This left three options: Boom clay, Ypresian clay or schist formations. The eventual reason Boom clay became the reference geological formation is simple and coincidental: it was available underneath the nuclear research centre SCK•CEN in Mol (interview N/O, 2011; interview SCK•CEN, 2011).

Although the international commission of experts that peer reviewed the SAFIR I report of 1989 agreed with the apparent suitability of Boom clay, it did suggest research into the characteristics of Ypresian clay as an alternative host formation (N/O, 2002, p.66). This recommendation was followed up by N/O throughout the years, but only to a limited degree. Some test drilling for instance took place in the nuclear zone of the NPP of Doel, where Ypresian clay is available. During the recent SEA procedure the strengthening of this potential alternative was again repeated (Minon, 2012; interview N/O, 2011; interview FOD Economy, 2011). N/O will follow up this recommendation, in first instance by investigating to which degree the knowledge of Boom clay can be transferred to Ypresian clay (interview FOD Economy, 2011; Minon, 2012). Although it does consider Ypresian clay as a potential alternative, N/O clearly states that it is financially impossible to do the same extensive in situ research (i.e. 30 years of dedicated URL experimentation) on another host rock than Boom clay. At this stage the latter thus remains to be the 'reference formation' (interview N/O, 2011).

FANC also requested the screening of other formations in the context of the recent SEA, referring again to schist formations (interview FANC, 2011; N/O 2011c, p.21). The primary, in our opinion socio-technical reasons why N/O prefers Boom clay over schist are the following (interview N/O, 2011): Boom clay has a plasticity which schist has not; if drilling would ever take place, the Boom clay will eventually close itself whereas schist will not. Moreover, Boom clay forms a homogenous layer which is spread under large regions in Belgium, which avoids a direct location issue (at least in theory, since, as pointed out before, after 30 years of experimentation in the URL in Mol, many automatically connect Boom clay to the Mol – Dessel region).

Concerns about the Boom clay layer not being deep (200 – 300 meters, compared to e.g. more than 500 meters of Oxfordian clay in France), thick and homogeneous enough were expressed throughout the public consultations on the Waste Plan (Minon, 2012). The 'Kempens Forum voor Atoomstop', a regional anti-nuclear movement, in collaboration with Greenpeace Belgium has organised a dedicated research and a public campaign to negate the suitability of the Boom clay in the North east of Belgium as a host formation for GD. The experts these organisations hired mainly point out the many remaining uncertainties, related both to the distant future, e.g. climate change, tectonics, and the potentially less distant future, e.g. related to chemical and thermal effects of the interaction

between the waste, the artificial barriers and the host geology or to the effect of fractures since the Boom clay is not completely homogenous (Wallace, 2010; Weyns, 2010). In the framework of the partnership of MONA some debate between the experts of N/O and SCK•CEN and those hired by the anti-nuclear movements has taken place, but without resolution. Proponents and opponents clearly seem to different about their understanding of 'rational expectancies'.

Process

As we have come to show, the choice for GD in clay was made early in Belgium, but in a rather isolated manner. After the publication of SAFIR I in 1989 and SAFIR II in 2001, only in 2004 did the government commission N/O with starting a societal dialogue and investigating all possible long term management strategies for cat. B & C waste (Verwilghen, 2004). The federal law of 13th February 2006 on the assessment of the environmental impact of plans and programmes and on the participation of the general public in the development of plans and programmes related to the environment[37] furthermore obliged N/O to set up a management plan and a supporting SEA for the long term management of all radioactive waste. The law provides in a standard 60 days public consultation procedure, during which comments can be submitted to the initiator of the plan or programme in question. Formal advise needs also be given by an ad hoc administrative advisory committee, assembling civil servants from related policy fields (e.g. sustainable development, public health, energy, …). N/O finally started with the establishment of this 'Waste Plan' and SEA in 2009.

N/O decided to go somewhat beyond the formal participatory aspects of the law. Before the submission of the Waste Plan and SEA for the formal 60 days consultation in the summer of 2010, three other types of consultations were organised based on draft versions of the documents and additional information. Throughout 2009 an interdisciplinary conference (set up to involve a broad variety of experts) and public dialogues (aimed to involve diverse societal actors) were organised in Brussels by N/O.[38] Furthermore, N/O asked an independent body, the King Baudouin Foundation (KBS) (a well-respected centre for philanthropy, fostering projects on justice, democracy and diversity) to organise another public consultation, which it did by means of a citizens' conference. During three weekends 32 Belgian citizens with diverse backgrounds gathered to study and discuss, among each other and in dialogue with experts, the long term management of high level and long lived waste to deliver a report with recommendations.

In spite of the additional efforts made, the process of the public consultations received quite some critique.[39] Holding a 60 days consultation process during the summer holidays was found inappropriate for such a complex topic by many stakeholders. N/O had tried to deal with this foreseeable complaint by organising additional efforts prior to the formal consultation. But the public dialogues, which indeed had a poor turnout, were reproached for being organized in a hidden place in Brussels without sincere means of prior information (about the event itself and its topic). And, in light of RWM being a clear case of unequally distributed costs and benefits, the citizens' conference

[37] Belgian transposition of the European Directives 2001/42/EC on SEA and 2003/35/EC on public participation in decision making in environmental matters for competences at the Federal level.

[38] Anti-nuclear movements Greenpeace, Bond Beter Leefmilieu and Fédération Inter Environnement Wallonie refused to participate in these initiatives.

[39] We base our overview of comments on the following references: Greenpeace Belgium (www.greenpeace.org/belgium/nl/wat-doen-we/kernenergie/kernafval-project-niras/), Interenvironnement Wallonie (www.iewonline.be/spip.php?article3711), the comments sent in by the Regional Nuclear Coordinationcel (RNC), comments from labour organisations (ACW/ACV, 2010), the report of the public dialogues (Dialogue Learning Centre, 2009), the explanation of the procedure and the analysis of the results by N/O (N/O, 2011d) and a presentation by N/O (Minon, 2012).

organized by the KBS was criticized because the technique focuses on the opinion of the 'average citizen' and ignores 'the potential local stakeholder'.
N/O agrees that the actual dialogue still needs to start, and that integrating the participative dynamics into the B & C programme has been largely ignored up until a few years ago (N/O 2011c, p.20). But apart from the additional public consultations organised in the framework of the Waste Plan, at present, it does not have a clear view on what participation on cat. B & C waste management should and could mean in practice, especially outside a concrete siting process. As mentioned before, this is when participation started for cat. A waste, and some actors today seem to think that it should not be different for cat. B & C waste (e.g. interview SCK•CEN, 2011; interview FANC, 2011).
One of the tangible recommendations from the public consultations was the creation of a permanent, independent body to the follow up of the process in the normative framework (KBS, 2010a, p.7). N/O itself supports this recommendation of the creation of a type of process 'guardian' (interview N/O, 2011; Minon, 2012).

Because after the elections in 2010 it took exceptionally long to form a new federal government, the Waste Plan remained 'in limbo' for over a year. Without formal approval or rejection of the final Waste Plan (including the outcomes of the public consultations as integrated by N/O) from the Federal Government, N/O has no formal basis to execute its plan or to draft a new one, as this would not tally with the procedures foreseen in the 2006 law. The new government has been installed since December 2011, but it has not yet taken the 'decision in principle' asked for by N/O. Although it is mentioned in the government policy statement, no reference to it can be found in the current policy documents of the responsible Minister of Economy and State Secretary of Energy (newspaper De Standaard, 25 January 2012)[40]. The same goes for the proposal for new legislation on the licencing procedure for definitive disposal, drafted by FANC in 2010. The proposal was submitted for public consultation at the end of 2010. Eleven replies were received.[41] A Royal Decree was drafted, but, again due to the long term absence of a federal government, it still has not been formally published.

The caretaker government did however recommend N/O to continue with the execution of its Waste Plan (N/O, 2011b)[42] after it had been approved by the Board of Directors of N/O, in which two government commissioners also have a seat. N/O thus continues the path of GD, taking into consideration the comments made through the public consultation. How the latter will be concretised, remains to be seen.

1.5 Timeline aid

1920: Union Minière (now UMICORE) starts exploiting the uranium mines in Katanga (former Belgian Congo).
1944: Belgian uranium for the Manhattan project leads to a "Memorandum of Understanding" between the USA, UK en Belgium.
1952: Foundation of the Belgian nuclear research Centre (SCK•CEN)
1956: Establishment of a waste department at SCK•CEN (first for its own waste, gradually also for other producers)
1959: Eurochemic, a prototype of a reprocessing, plant is set up within the framework of the OECD.
1962: The first European pressurised water reactor becomes operational at SCK•CEN, the BR3.
1967: Start of systematic sea dumping of Belgian low level waste into the North Sea
1974: SCK•CEN starts it's R&D programme on HLW, focussed on geological disposal.

[40] Opinion piece by a parliament member of the green party.
[41] See www.fanc.fgov.be (Accessed: 17/02/12)
[42] Letter of 3 October 2011 from Minister Magnette and Minister Van Quickenborne . A summary of this letter can be found at www.niras-afvalplan.be/nieuw/web/ezines/news_nov2011_Niras_nl.html

1975: Reactors Doel 1+2 en Tihange 1 go into operation. In light of the launching of nuclear energy production, Belgowaste, a think-thank on future RWM between the government and main private RW producers is founded.
An application for a fourth reactor in Zeebrugge receives heavy protest; the anti-nuclear movement develops.
1980: Start HADES project at SCK•CEN, an URL in deep Boom clay
Foundation of NIRAS/ONDRAF
1982: N/O becomes operational and gradually takes over the RWM activities of SCK•CEN.
'82-85: Doel 3 + 4 en Tihange 2 + 3 go into operation.
1983: The London Convention leads to a moratorium on sea dumping, bringing the short term management of LILW to the foreground.
1987: The Transnuklear scandal, a bribery case related to transports of foreign RW, surfaces
N/O publishes the first siting studies for LILW, which causes heavy local public resistance
1988: A moratorium on nuclear new build is approved.
1989: Publication of SAFIR I, summarizing R&D work on HLW and deep geological disposal between 1974 and 1989.
1993: MOX-debate, a moratorium on reprocessing is approved.
1994: Foundation of the Federal Agency for Nuclear Control (FANC) by the merging of two units formerly belonging to different ministerial departments (operational in 2001).
N/O proposes potential sites for LILW disposal after desk top research (NIROND 94-04); all municipalities refuse.
1998: The government elaborates N/O mandate to also include societal aspects.
1999 - 2003: Three local partnerships for siting of LILW repository are established.
2001: N/O produces SAFIR 2 summarizing R&D work on HLW between 1990 – 2000.
2003: The phase out law is approved (prohibition on new build and phase out of existing reactors between 2014 and 2025) (no preceding public debate).
2004: The government commissions N/O with investigating different alternatives for the long term management of HLW waste.
2005: N/O and SCK•CEN form an economic interest group around HADES, EURIDICE.
2006: Dessel site is selected for LILW surface disposal.
2009: Proposal to put the phase out plan back by ten years (three of the reactors due to close in 2015 will now remain open until 2025) (no preceding public debate). Government falls before the proposal is put into practice.
N/O launches the debate on cat. B & C waste with public consultations on its draft Waste Plan and SEA.
2010: Belgian Government agrees with 40% financial support for MYRRHA, a new research reactor project led by SCK•CEN, with a holding point at the end of 2014 for thorough review (no preceding public debate).
2011: After the N/O Board of Directors approves the Waste Plan internally, it is offered to the caretaker government and later to the newly elected government.

2 Socio-technical challenges

2.1 Division of responsibilities

Throughout section 1 we described how, fundamentally, the Belgian RWM landscape is shaped by the classical triangle composed of producer – implementer (N/O) – regulator (FANC). Nevertheless, we also already indicated that there is a wider variety of actors and that the interactions between them (both among the actors within the triangle as between those three parties and other actors)

reveal what we would describe as socio-technical complexity. In this section we will outline this further and indicate how regulatory, political, economic and even linguistic factors (may) interact with technical aspects. The examples given can be considered as part of a more systemic socio-technical connection between responsibilities, waste characterisation and inventory making, and technical options.

2.1.1 RW delineations

Although it is responsible for the management of all radioactive materials in the country, it is not N/O that defines what RW is.[43] Summarized, the identification of substances as 'radioactive' lies with FANC, and the identification of substances as 'waste' lies with the producer / owner. The management of quantities of enriched fissile materials and plutonium-bearing materials thus belongs to the responsibility of N/O only insofar as these materials are formally declared in excess. As long as these materials are not declared in excess, its management remains the responsibility of the owner / producer (Bergmans and Van Steenberge, 2006, p.42; interview N/O, 2011). With the aim to prevent nuclear legacies, in 1997 the task of keeping an inventory of all nuclear installations and sites and the radioactive substances they contain was added to N/O responsibilities.[44] N/O has the obligation to revise this waste inventory, containing both technical and financial information, every five years (Laes et al., 2007, p.182), but, being dependent on a variety of others, this is not an easy task.

A similar problem exists for SF, which is kept in temporary storage at the NPP sites and not considered waste until its owner, Synatom, decides to hand it over to N/O. Although Belgium was a pioneer with regard to reprocessing and the development of MOX fuel (cf. also footnote 21), since 1993 there exists a moratorium on reprocessing. This decision has to do with a lot of factors including financial, political, historical and technological aspects connected to the choice between an open or closed fuel cycle (cf. Laes et al. 2007, p. 189 – 192).[45] At the time, parliament asked the government to collect arguments for a new evaluation of this moratorium, after which a new debate would be held (planned to take place five years later, i.e. in 1998). Up until today, this debate has not taken place, and the moratorium remains in place. In 2005 it was decided that the MOX fuel production factory Belgonucléaire would be closed. Thus cat. C waste today basically only refers to high-level vitrified waste.
Summarized, whether spent fuel and remaining fissile material and plutonium containing materials from previous reprocessing activities are potential resources or waste, remains unclear. This complicates N/O's job of making an inventory of what is out there, as these materials remain the property of their original producers. Consequently it burdens its strategies both with regard to designing the future disposal, technically and economically, as with regard to public communication (interview N/O, 2011; N/O 2011c, p.22) (see also annex 1).

[43] The law defines RW as "each substance for which no possible use is foreseen and which contains radionuclides in a higher concentration than the values considered acceptable by the competent authority to be used or disposed without supervision"(Royal Decree of 30 March 1981, article 1, own translation).
[44] Programme law 12 December 1997 concerning diverse regulations (BS 18 December 1997, 34132).
[45] The initial enthusiasm about the technology of combining reprocessing with breeder reactors dwindled towards the end of the eighties, caused by economic, technical and safety related concerns, mainly concentrated around the breeder project in Kalkar (Germany). Following these evolutions, Belgian producers chose to opt for the more limited recycling technology of reprocessing in combination with the use of MOX fuel. Spurred by the licencing of a larger MOX production capacity of Belgonucléaire, a parliamentary debate took place in 1993 about the future of the Belgian nuclear fuel cycle (open, closed, or combined) and the potential use of MOX fuel in two of the Belgian reactors. In December 1993 the 'MOX resolution' (cf. footnote 13) was passed. The strategy of reprocessing would no longer be favoured over direct disposal of spent fuel in future policy making and research and new reprocessing contracts were postponed for five years. Cf. also Laes et al. 2007, p.174 – 177.

2.1.2 Techno-economic challenges

Although N/O is responsible for the long term management of all RW, its position with regard to the provisions for the RW of the current commercial reactors is not particularly strong. Quite some debate exists about the transparency of Synatom, the company responsible for these provisions, and the way it manages its funds (e.g. Laes et al., 2007, p.242 – 243). The Belgian State holds a 'golden share' in Synatom and the Commission for Nuclear Provisions, a follow up committee of governmental and administrative actors (e.g. the Federal Department of Energy, the National Bank of Belgium), was set in place to advise on the methods used to set up and manage the provisions and to control their application. Nevertheless it fundamentally remains a 100% daughter of GdF Suez Electrabel. It can moreover be considered odd that Synatom itself is also represented in the Commission for Nuclear Provisions, whereas the directors-general of FANC and N/O only have an advisory role. N/O has recently introduced a court claim against this Commission in order to increase the amount of the decommissioning fund (Newspaper De Morgen 21/02/12 (titled "Quarrel over nuclear waste bill"), cf. also N/O, 2011a, p.66).

The existence of a 'permanent technical committee' within the organisational structure of N/O has also been criticized by some actors (e.g. Barbé, 2004). This committee is made up of representatives from the waste producers that finance the agency and advises N/O's board of directors.
More fundamentally, the law that stipulates the tasks and working modalities of N/O states that the agency will "define the R&D programmes which are necessary for the fulfilment of its mission *in cooperation with the producers*"(Royal Decree of 30 March 1981, art. 4b, own translation and italics). When this law was formulated nuclear power production was still strongly connected to the Belgian State, so a certain degree of self-regulation was not deemed problematic. But in the context of a liberalized energy market these stipulations should be scrutinized. Another reason for this is the potential spill over effect of the tensions between governmental actors and the private sector, notably nuclear operator GdF Suez Electrabel, due to the ambiguous deliberations in the context of the phase out law (cf. section 1.1, footnote 10). This debate is also closely linked to the nuclear taxes the government decided to impose on the profits made on the continuous use of nuclear reactors after their fiscal depreciation ('windfall profits tax'). Recalling the previously explained legal stipulations, it is not inconceivable that these tensions may have repercussions on the techno-economic RWM cooperation between N/O and the producers.

2.1.3 A transversal approach?

In the context of the previously described fuzzy division of responsibilities, N/O added a specific section on "Proposals and recommendations on related issues the answers to which are not a matter solely for ONDRAF/NIRAS" to the Waste Plan. In this section it asks for clarifications and specifications with regard to both a regulatory framework and the anticipated volumes and characterisations of cat. B & C waste to be disposed (N/O, 2011c, p.22). Positioned between the government, the regulator, the producers and the research centres, N/O more generally urges the need for a *transversal approach* (interview N/O, 2011). Although no party will deny the usefulness and necessity of a transversal approach in RWM in theory, in practice this vision does not always seem easy to implement.

The (de)connection between debates on nuclear energy and debates on nuclear waste clearly illustrates this point. Broadly studying the Belgian energy policy and the role of nuclear within this

policy has been mandated to several expert commissions in the past[46], all of which referred to RW as a critical issue. The other way around, nuclear energy as a whole has also come up in every public debate about RWM (also in the framework of the Waste Plan (N/O, 2011d; Minon, 2012)). Although the future of nuclear energy in Belgium obviously has an influence on RWM, such decisions depend on the State, the producers and FANC, and N/O underlines that this debate goes beyond its mandate: "The task of N/O is limited to the management of RW on the short and on the long term. Therefore, in the Waste Plan or in the related dialogue, no mentioning can be made of proposals about for instance the energy policy of the government or future nuclear projects (that lead to RW)" (N/O, 2008, p.1). Nevertheless, opponents see a strong connection between GD and the continuation of nuclear energy (interview Greenpeace, 2011).[47]

The continued undecided status of SF (ultimate waste or resource) also seems to be connected to the debate about the future of nuclear energy. And a similar ambiguous mixture of nuclear waste and nuclear energy can be found in relation to advanced nuclear technologies, for instance in the context of the MYRRHA project proposed by SCK•CEN (cf. section 2.6).

Decisions with regard to changes in the exploitation of the current reactors that influence the amount and characteristics of the RW (e.g. higher burn up of the fuel) are also not characterized by a transversal approach. When licencing changes are proposed N/O does not have to be consulted and FANC checks the safety impact of changes with regard to the installation under consideration, but not for potential impact on the disposal facility, since this not yet exists and no dedicated regulatory framework is yet in place (i.e. no licencing conditions) (interview N/O, 2011).[48]

Summarized, the socio-technical character of RWM seems at once to necessitate and to complicate a transversal approach through the divisional fuzziness between nuclear energy, nuclear safety and nuclear waste.

2.2 Reversibility and Retrievability

At present, there are no requirements defined with regard to reversibility and / or retrievability in the Belgian law. Whereas **storage** is legally defined as "temporary storage with the aim and in such a manner as to enable later retrieval", the legal definition of **disposal** clearly stipulates "without the intention of retrieval".[49] It is thus connected to an understanding of RW as 'ultimate' waste and of disposal as 'final' disposal.

2.2.1 R&R for LILW and surface disposal

The idea of R&R already came up in public debate in the late seventies – early eighties, as irreversibility and irretrievability were important arguments in the protest against dumping LILW into the sea (Laes et al., 2007, p.144; interview Greenpeace, 2011). The notion of reversibility officially entered the Belgian RWM discourse in the late nineties. Undoubtedly inspired by legislation of neighbouring country France, the governmental decision of January 16th 1998 regarding a long-term solution for cat. A waste prescribes N/O to opt for (Bergmans, 2005, p.260):

[46] To mention the three latest ones, the AMPERE Commission delivered its report in October 2002, the Commission Energy 2030 in June 2007, and the GEMIX report was issued in October 2009.

[47] See also www.greenpeace.org/belgium/nl/wat-doen-we/kernenergie/kernafval-project-niras/ (Accessed: 06/03/12)

[48] It may also be mentioned that, concurrent with the preparation of a new licencing proposal for final disposals, a reorganisation took place within FANC, splitting the waste department from the general licencing department (interview FANC, 2011).

[49] Law of 11 January 1991 replacing article 179, §2 of the law of 8 August 1980 concerning the budgetary proposals 1979-1980 (BS 12 February 1991, 2797). Own translation.

- A final repository, or at least one that could progressively become final
- which can be implemented in a phased and flexible manner
- and should be reversible.

The call for R&R also became confirmed by the local partnerships. The reasoning behind this condition among the local communities was to ensure that the waste could be taken back, both in case of problems or in case of new and better management solutions (STOLA, 2004, p.25). R&R is indeed integrated into the current design of the future LILW surface repository, without posing great technical challenges.

2.2.2 R&R for HLW and geological disposal

Within the framework of SAFIR I (published in 1989) N/O did not dedicate research to R&R and clearly speaks of GD as "definitive and irreversible disposal" (N/O, 1989, Foreword, p.1). In contrast to SAFIR I, R&R are treated rather elaborately in SAFIR II (chapter 12 is dedicated to the topic). The main focus however remained the same: the aim of GD is to be a *final* destination for *ultimate* waste by means of *passive* safety. R&R is thus described as unnecessary. It should not be interpreted as contributing to long term safety, and by no means may it jeopardize safety or security: "retrievability can never be a reason for reducing or compromising the passive long-term safety of the disposal system, nor be seen as a way of compensating for its possible shortcomings" (Ibidem, p.14). At the same time however, in SAFIR II it is emphasized that "there is no fundamental contradiction between disposal (no intention to retrieve the waste) and retrievability (the possibility of retrieving the waste from the repository *during a certain period of time*)" (N/O 2001a, chapter 12, p.2, own italics).
We agree with Bergmans and Van Steenberge that it "feels fare to state that the difference between SAFIR I and II not so much lies in fundamental differences in the concept design, but in the emphasis laid on either one of the two major phases of the repository's lifecycle, namely a pre-closure and post-closure phase" (Bergmans & Van Steenberge, 2006, p.36). In the active, pre-closure disposal phase, retrievability is described as an element of operational safety throughout SAFIR II (N/O, 2001a, p.15). But the report clearly dissuades from leaving the disposal open for much longer than the disposal activities last, for which various arguments are mentioned:

- Firstly, keeping the repository open to enable R&R may lead to a negative impact on **safety**. The reasons given are connected to both technical processes (related to the presence of oxygen and heat, stability of the gallery walls, …) and social processes (loss of adequate maintenance, monitoring, know how, finances) (Ibidem, p.16).
- Secondly it is pointed out that there are no arguments for long term R&R: "The decision to place the waste in an underground repository implies that there is broad consensus that the disposal of the waste represents an acceptable and safe solution. It also implies that there is no longer any intention to retrieve the waste" (Ibidem, p.12).
- Thirdly potential impacts of R&R on the **cost** of the disposal facility are also pointed out (N/O, 2001b, p.21).

These arguments explain the plan to backfill and seal both the main galleries as well as the shafts (cf. also annex 2) quite soon after the waste emplacement has taken place.

Nevertheless, some doubt may be discerned throughout SAFIR II, namely with regard to SF. In the context of cat. C waste it is mentioned that the repository design "contains a number of attributes which, although developed solely on grounds of safety considerations, make it possible for the waste to be retrieved within a certain period of time. The two most important attributes are the waste canister and its overpack, both with long design lives" (Ibidem, p.12). Although it is pointed out that backfilling makes R&R considerably more difficult, the argument is made that these two attributes enable a relatively simple handling and thus potential retrieval of this waste over a long time period (ca. 1000 years) (Ibidem, p.13; N/O, 2011a, p.136). Moreover, after the artificial barriers can be expected to have lost their integrity (several 1000s of years (interview N/O, 2011)), the waste can no

longer be considered “intrinsically retrievable”, but will still be “possibly retrievable” (N/O 2001a, p.14). Retrievability thus never seems to be perceived as completely impossible. An important socio-technical argument seems to be at play here, namely that we simply cannot and should not try to predict or control the future: “one cannot expect or require that the decisions that our generation can take with respect to retrievability will still have an effect on generations at such distant times in the future” (Idem; interview SCK•CEN).

2.2.3 Socio-technical arguments in the Belgian understanding of R&R

Today, N/O and FANC have developed their own understanding of R&R, which seems to somehow differ from the definition of the concepts by the international community (e.g. OECD NEA, 2001, OECD NEA, 2011).
N/O and FANC use the concept **reversibility** to denote the taking back of the waste by means of the same or very similar operations and equipment that were used to place the waste into the disposal. Reversibility therefore is restricted to the exploitation phase within the operational period, i.e. before closure of an individual disposal gallery (N/O 2011a, p.135; Blommaert, 2010, p.4).
Retrievability is used to refer to the taking back of the waste after partial or full closure, which will require different operations and equipment than used to fill the disposal (Idem).
Recoverability is used to denote the retrieval of the waste in the far future, when the artificial barriers can no longer be expected to be intact (Blommaert, 2010, p.5) (in SAFIR II referred to as “possible retrievability”).
For both FANC and N/O, the notion of **flexibility**, as part of a stepwise implementation process, is more important than the technical notions of R&R. Flexibility (also limited to the operational phase) refers to “the capability and the willingness to re-assess earlier decisions and the ability to reverse the course of action or decision to a previous stage” (Ibidem, p.4), especially in view of the long time frames the implementation phase involves. In the definition of FANC and N/O, reversibility may be part of flexibility, but retrievability is not.

These Belgian definitions in our opinion reveal the socio-technical nature of R&R, as they couple certain technical provisions and actions with certain societal, political and economic motivations and actions. For FANC reversibility (i.e. pre-closure) may have both ‘technical’ and ‘social’ reasons: “This reversal in process step(s) may be of different origin: it may be purely political, societal or economical, technical or environmental or it might be related to the safety associated with waste emplacement operations as such” (Blommaert, 2010, p.4). This mixture is not the case for retrievability (post-closure), where reasons can only be social in nature according to FANC. The regulator argues that the transition towards the sealed, final configuration will only be licenced when sufficient arguments and evidence are provided to prove the disposal complies with the safety case and the licence application. When this is the case, retrievability is no longer needed from a safety point of view and hence should not be imposed by the regulator. “It may however be imposed politically or for reasons of public acceptance, rather than based on safety arguments” (Blommaert, 2010, p.5). FANC warns for the deceitful expectations R&R may create with the public, namely a false feeling of safety. Confidence should not depend on the ability to bring waste back to the surface, but on argumentation and demonstration of passive, long term safety (interview FANC, 2011).

It is interesting to see that ‘more socially orientated stakeholders’ seem to defend long term retrievability on what may be classically referred to as ‘more technical’ grounds. The reasons mentioned throughout the public consultations on the Waste Plan (KBS, 2010a, p.18) are similar to those formulated by the local partnerships for the LILW repository:

- technologies continuously evolve;
- further research may reveal a better solution;
- reversibility adds to the robustness and safety of the disposal.

On the other hand 'more technically orientated people' seem to think it is based in what classically would be referred to as 'social' grounds. In SAFIR II for instance the following reasons for long term R&R are discerned (N/O, 2001a, chapter 12, p.6 – 8):

- the precautionary principle;
- aspects of inter-generational equity (not passing on an undue burden to future generations);
- potentially different future value estimations of 'waste';
- potentially different future risk perception (R&R having a possible positive effect on risk perception due to feelings of control and feelings of an ability to 'undo').

Furthermore, in connection to safety, for what we previously referred to as 'the more technically orientated people', the idea of R&R as a loophole is downright improper (cf. supra), while for 'the more socially orientated people' it is point-blank appropriate (e.g. interview Greenpeace, 2011).

2.2.4 R&R prospects

In the newly proposed legislation on the licencing procedure for definitive disposal (cf. also section 1.2), FANC states that the public ought to have a say about the moment of final closure, which means, in their vision, about the moment when 'intrinsic retrievability' ends (interview FANC, 2011).
In the Waste Plan N/O states that it will investigate the recommendations on R&R as formulated throughout the public consultations, but it will not depart from the law which defines disposal 'without the intention to retrieve'. The Waste Plan does mention that possibly design measures will be taken that can ease R&R over time, e.g. by backfilling with "light" cement material (N/O, 2011a, p.137). In a NEA report that summarised the responses to a R&R questionnaire issued to NEA member countries in 2008, one reads that for Belgium, the issue of R&R will be dealt with specifically in the context of the first Safety and Feasibility Case (estimated to be prepared in 2013) (OECD NEA, 2010b, p.2).
Summarized, it remains to be investigated and explicated to what extent the public's interpretation and use of the notions of R&R match with that of FANC and N/O. An in our opinion crucial socio-technical issue that may be pointed out more explicitly in this regard is that passive safety is not only the goal, but also the point of departure of GD. A GD system is intrinsically designed to be passive; as long as you do not backfill and close it as planned, it does not answer to the conditions you presumed throughout your research, which heightens uncertainties and may lead to the requirement of active intervention (e.g. ventilation) (interview N/O, 2011). It therefore comes as no real surprise that, as things stand today, the regulator will probably add reversibility (as it itself defines it) to the licencing conditions, but it does not have the intention to add post closure retrievability to the regulatory framework (N/O, 2011a, p.136; interview FANC, 2011), since "the aim of GD is exactly not to get it back" (interview FANC, 2011).

2.3 Monitoring and Controllability

Monitoring and controllability already came up as an in our opinion clearly socio-technical challenge in the framework of LILW in Belgium. Permanent monitoring of effects regarding environment, safety and health, and long term control of the cat. A waste surface repository were formulated as explicit conditions by the local partnerships, in connection to a perceived added value to safety and confidence (STORA, 2004, p.24 and p.25; MONA, 2005, p.63). Although it was not foreseen in the original design of the surface repository, STOLA concretely requested an inspection gallery underneath the repository (STOLA, 2004, p.30). Such an inspection space would enhance the detection of cracks and leaks and enable consequent action (Ibidem, p.31). N/O granted the demand,

but FANC expressed technical concerns related to safety. Eventually an in our view socio-technical compromise was elaborated, keeping the inspection room, but with a reduced height.

From the public consultations held in the framework of the Waste Plan it became apparent that, also for GD, certain stakeholders desire additional controls to those that will be foreseen by the regulatory framework (whether related to the actual licencing conditions or to safeguards) (N/O, 2011a, p.138). The Waste Plan itself only mentions the term 'monitoring' at one point, namely when referring to regulatory controls likely to be imposed by FANC (Ibidem, p.139):

> *With regard to regulatory control in the period after waste emplacement, FANC currently envisages:*
> - *a monitoring and surveillance programme after closure of the emplacement galleries;*
> - *a monitoring and surveillance programme after the full closure of the facility. This programme, in a first phase primarily dedicated to active measurements (avoiding intrusions, surveillance over the condition of the installation, …) will gradually evolve on the long term to a merely passive programme (avoiding the risk of intrusion, e.g. by permanent markers).*
>
> *The length of these monitoring and surveillance programmes still needs to be determined.*

Despite this limited explicit mentioning of monitoring throughout the Waste Plan, N/O does clearly recognise a societal demand for additional forms of control "both during operation and closure, as well as after closure of the disposal facility to verify its correct functioning" (N/O, 2011a, p.138, own translation). The letter from the caretaker government to set a framework for further work after the Waste Plan and in attendance of a decision in principle on GD clearly holds N/O to its intention, by asking the agency to clarify "in consultation with all parties concerned, the societal demands regarding" among others "the control over the proper functioning of the disposal system" (N/O 2011b, own translation).
Public consultation on the Waste Plan as well as evolutions in other countries and on the international level (e.g. the MoDeRn research project[50]) thus seem to have put monitoring in relation to GD as an issue on the Belgian waste managers agenda. N/O expresses the intention to further determine the outline of the conditions for controllability in dialogue with society, immediately warning however that it cannot be expected that such a system of control be maintained for eternity. Gradual closure of the facility, it is argued, will entail ever more indirect forms of control, and thus limit the timeframe within which a control (or monitoring) programme will be feasible to maintain (Ibidem, p.139).
It can be argued that, as for R&R, the unresolved socio-technical challenge includes both the duration and the scope of monitoring and controllability. Already at the time of the SAFIR II report, N/O recognized monitoring as a complex issue and as what we would refer to as a socio-technical challenge: "In practice, monitoring can be used both technically and socially as an instrument of decision-making" (N/O 2001a, chapter 9, p.7) – "The precise role of a monitoring programme, both before and after the closure of the repository, must be defined, as must the relationship between monitoring and retrievability" (Ibidem, chapter 12, p.18).

Where the 'social side' of the challenge is at present still ill-defined and unclear, beyond references made by N/O staff to a "clear and recurrent demand for controllability" (Lalieux, 2011), the 'technical' challenges are somewhat better known, and directly related to the primary function of GD as providing for passive safety.
N/O in this respect states that it "undertakes to continue the controls of the repository's functioning which will be performed in addition to regulatory controls for a period that still has to be agreed upon with the stakeholders. However, these controls cannot be performed at the expense of

[50] The MoDeRn project (Monitoring Developments for Safe Repository Operation and staged Closure) is a collaborative project funded by the European Atomic Energy Community's Seventh Framework Programme (FP7/2007-2011) under grant agreement n° 232598.

perturbations of the system and thus of its proper functioning" (N/O, 2011c, p.21). This argument is made both in view of monitoring during operations and closure of a facility, but even more explicit with regard to the situation after closure. This point was also made at a conference dedicated to 30 years of URL experience, held in 2011. The added value of insights from 10 years of monitoring in HADES for the future GD was highlighted, but at the same emphasize was put on the fact that the same level of monitoring for an actual disposal as compared to an URL is challenging, since equipment may disturb the system. The main challenge with regard to monitoring thus became defined as finding a balance between control and disturbance (Lalieux and Van Geet, 2011). The same issue of potentially creating preferential 'escape routes' for radionuclides was made during an interview at the Directorate-General for Economy (interview FOD Economy, 2011).
FANC furthermore points out that monitoring is not a safety item in itself. "The only goal of monitoring is to verify the predicted functioning of the GD" (interview FANC, 2011). FANC makes a clear connection between the duration of the licence and the operational phase of the GD facility, and thus the existence of an 'implementer' in the legal sense. On the one hand the agency declares that "Even if the repository is technically closed, this does not mean that the repository site will be abandoned immediately and left without further surveillance / monitoring" (Blommaert, 2010, p.7). On the other hand, it also points out that it is not clear who will be in charge of conducting such programmes after the termination of the licence, nor of interpreting the results and taking potential action (interview FANC, 2011).
It thus remains to be seen whether a socio-technical compromise as it was found for LILW will also be feasible for HLW.

2.4 Preservation and transfer of knowledge and memory

Connected to both R&R and monitoring and controllability in manners yet to be further explored, is the topic of long term knowledge and memory preservation. In the context of R&R, in SAFIR II it is for instance mentioned that "the importance of transferring and archiving knowledge about the repository becomes very clear …. Retrievability only remains an option if future generations have access to accurate and specific information about the disposal system (e.g. the location, local geology, construction details, waste packages characteristics etc.)" (N/O 2001b, p.13).
Many challenges remain with regard to this topic, related to what information should be preserved and how it can be transferred, but also with regard to the fundamental question of why we want to do so.

An important reasoning behind the rationale of GD is that it's long term safety basis depends on foreseeable, stable, passive, technical elements (the artificial barriers and the geology), and not on unpredictable, unstable, active future human action. As mentioned before, geological stability is thus trusted over socio-political stability (N/O, 2001a, Introduction, p.9). However, it is realized that one cannot make complete abstraction of this socio-political environment either.
In the past, some research has been dedicated to potential human intrusion scenarios and the health effect these may have (also advised by the Evaluation Commission of SAFIR I (1989, p.13)). In other countries, e.g. the USA, how to avoid such potential intrusion scenarios has also been and continues to be an object of study.[51] Today, the issue at stake is interpreted broader than simply warning people to stay away. More and more voices seem to point in the direction of a need to complement passive, material controls (such as markers) with more diverse and also active means of information

[51] See for instance the Passive Institutional Controls programme at WIPP, www.wipp.energy.gov/picsprog/pics_general.htm (Accessed: 09/03/12)

transfer.[52] Knowledge and memory preservation about GD thus clearly seems to require a socio-technical approach, both with regard to its content and its processes.

Also within both the N/O dialogues and the citizens' conference organised by KBS the long term preservation of knowledge by means of a sort of "collective memory" (KBS, 2010b, p.16) was an important theme. Communication from one generation to another was judged to be a realistic way (Dialogue Learning Centre, 2009, p.24). Education and training were judged "useful and even necessary means" (KBS, 2010a, p.32).
N/O addresses these commentaries in the final Waste Plan. It points out that the transfer of knowledge and the preservation of memory of GD indeed includes two elements: the marking of the site and the transfer of knowledge and knowhow (N/O, 2011a, p.140). The Waste Plan connects it to the preservation of societal support (N/O, 2011a, p.167) and to keeping the option of R&R open. Greenpeace follows a somewhat opposite reasoning, pointing out the inherent added value of retrievability, precisely "because it entails the preservation of consciousness" (interview Greenpeace, 2011). GD as an irretrievable, passive management method is judged to have oblivion inscribed into its logic, which, according to Greenpeace, is doomed to lead to trouble on the longer term (Idem).

When talking about transgenerational knowledge preservation and transfer, it is interesting to firstly investigate the situation in an intra-generational context, which also reveals an entanglement between the social and the technical. At the previously mentioned conference on 30 years of experience with URLs, it was stated that such laboratories also play a role in memory keeping and the continuity of knowledge (Lalieux and Van Geet, 2011). On the other hand, it was also mentioned that, after 30 years of operation, the first generation of HADES collaborators are retiring, taking with them a large amount of historical meta data. One speaker pointed out that every single step that was taken during these 30 years is documented, but for example the rationale for the steps are not, nor are the failures. Related to this remark, quite some actors point out potential problems with regard to knowledge preservation in light of the potential decline of nuclear energy and thus potentially nuclear research (interview SCK•CEN, 2011; interview N/O, 2011). The fact that the number of masters in nuclear engineering graduating from Belgian universities is declining, was already pointed out at the time of SAFIR II, notably in connection to maintaining the necessary capacities needed to uphold the RD&D programmes on the required quality level (N/O, 2001b, p.10). It is again repeated throughout the Waste Plan, as another argument for the need to start implementing a final, passive RWM strategy as soon as possible (N/O, 2011a, p.77). The interviewee of SCK•CEN also pointed out that for reasons of potential loss of knowledge and knowhow, prolonged interim storage, e.g. until all SF has cooled down, before taking action on a final management strategy is inherently risky (interview SCK•CEN, 2011). Greenpeace on the contrary points out that the end of nuclear energy production will not mean the end of radioactive waste production (as for example the medical sector will continue to generate radioactive wastes), and thus not of related knowledge, although for instance subsidized education may be necessary (interview Greenpeace, 2011).

Notwithstanding the fact that awareness of the difficulties of knowledge preservation and transfer exists, no active measures are currently taken to explicitly tackle the issue in Belgian RWM. In the Waste Plan one reads that "In the coming years ONDRAF/NIRAS proposes to develop a systematic solution to this problem and one that will guarantee the lasting availability of this acquired knowledge" (chapter 7, p.18). This intention however was already expressed at the time of SAFIR II: "One of the priorities for the third phase of the methodological research and development programme mentioned is defining and developing a long-term management and transfer system of the knowledge acquired enabling, in particular, the traceability of decisions and technical choices made, and the transfer, integration, and synthesis of multidisciplinary information" (N/O, 2001c, p.9). Although one is aware of the fact that memory is already being lost (cf. the previous comment about

[52] See for instance www.oecd-nea.org/rwm/rkm/ (Accessed: 09/03/12)

retiring HADES collaborators), one may assume that without a political decision on GD and a clear framework for implementation, there has not been a true sense of urgency to pursue this intention.
FANC also tends to agree that memory keeping probably is a good thing, but it has not developed a dedicated regulatory framework (interview FANC, 2011).
N/O did recently join a NEA project dedicated to the long term preservation of records, knowledge and memory.[53]

Although the full lifetime of surface repositories may be comparable to the implementation time of geological disposal facilities, some inspiration for the topic of knowledge and memory preservation may perhaps be found within the Belgian case of cat. A waste. In their final reports, both MONA and STOLA asked for a local fund that should last for at least the life time of the repository (MONA, 2005; STOLA, 2004). A number of sustainability criteria for potential beneficiary projects of this fund are currently being developed, among which the degree in which projects create a long term link with the repository (MONA, 2005, p.101). Both partnerships moreover requested continued participation. STOLA also asked for a broadly conceived communication centre in the vicinity of the repository. All these conditions can be said to concretize the socio-technical character of the repository and RWM at large, by aiming to create a lasting visibility of the link between the 'socio-economic realizations' and the LILW repository from which they originate (Laes et al., 2008, p.32).

2.5 RWM and advanced nuclear technologies

Whereas the previous section focused on the preservation and transfer of existing knowledge, the development and follow up of new knowledge and advanced technologies was also an important theme within the public consultations surrounding the Waste Plan (e.g. KBS 2010a, p.20; ACW/ACV, 2010; Minon, 2012).
The option of "waiting for advanced nuclear technologies" was however presented as an invalid RWM approach by N/O throughout its documentation for the public consultations, stating that such technologies will only be potentially applicable for SF and will moreover also create ultimate waste that will have to be managed on the long term (Dialogue Learning Centre, 2009, p.13). The SEA was also negative about it, highlighting that applying the technology of partitioning and transmutation on an industrial scale will only be applicable for Generation IV reactors, and that it is a very slow process which requires a cycle of at least a 100 years to reach a considerable diminishment of the amount of actinides (Resource Analysis et al., 2010, p.118). It would thus require a long term commitment for electricity production with nuclear energy, which would moreover require intensive research on almost all steps of the nuclear fuel cycle (Ibidem, p.120). This point was also already made by N/O in SAFIR II: "The extent to which partitioning and transmutation can make a significant contribution to the long-term management of radioactive waste in the future remains an open question. In any event, major and very far-reaching technical, social and economic choices and judgements would have to be made in order to develop this technological option into an operational possibility" (N/O, 2001a, chapter 1, p. 4).

The main point throughout the documentation for the Waste Plan consultations in the context of RWM and advanced nuclear technologies may thus be summarized as the need to make a fundamental difference between the current waste and potential future waste (Resource Analysis et al., 2010, p.117). Against this background, it can be considered perhaps somewhat surprising that the public consultations on N/O's Waste Plan nevertheless revealed such an interest for the topic. The public does indeed seem eager to hear about new technologies that address the issue of nuclear waste. Media reporting on for instance the MYRRHA project led by SCK•CEN has at times also been

[53] See www.oecd-nea.org/rwm/rkm/ (Accessed: 09/03/12)

very optimistic (e.g. "SCK finds the key to a quicker processing of nuclear waste")[54]. To replace the BR2 research reactor, operational since 1962, SCK•CEN is planning to build MYRRHA (Multipurpose Hybrid Research Reactor for High-tech Applications) at its site in Mol. MYRRHA is conceived as a fast spectrum research reactor coupled to an accelerator driven system. It would be used to try and demonstrate the technology of accelerator driven systems and to study transmutation of long-lived radionuclides in nuclear waste. Later on it is intended to be run as a critical fast neutron facility, for fuel research, materials research for Generation IV reactors and for the production of radioisotopes and doped silicon (World Nuclear Association, 2012).[55]

Bringing the previously outlined argumentation of the SEA back in mind, a project proposal like MYRRHA reflects some of the complex socio-technical challenges at the interface between RWM and nuclear energy policy (cf. also section 2.1.3). Throughout discussions about the project, e.g. a debate organised in Mol by the regional green party (1 October 2011), multiple different interpretations can be detected about for instance the exact meaning and bearing of the Belgian phase-out law, or about the 'correct' means and implications of wanting to preserve nuclear know-how in the country.

In May 2010, the Belgian Government agreed with 40% financial support for the MYRRHA project, with a holding point at the end of 2014 for thorough review. The remaining money is being sought from international partners. N/O does not contribute to this research, nor does Synatom.
In the final Waste Plan, N/O commits to "following up national and international developments in the field of advanced nuclear technologies", but makes a statement by adding "although these technologies will not make any contribution to the long-term management of existing and planned conditioned waste" (N/O, 2011c, p.21). The only reasons why following up these developments is justified according to N/O, is because of the uncertainty surrounding the status of commercial SF and "because these technologies themselves will produce waste that will need to be managed on the long term" (Idem).

3 Round up

This report aimed to elucidate the socio-technical character of GD by exploring the Belgian case RWM. Throughout the first section we tried to give an overview of the historically developed state of affairs of RWM in Belgium. We explained that, although GD in Boom clay has been the reference solution from the start and dedicated research has steadily continued (cf. table 1), up until today there exists no official long term management policy for cat. B & C waste (including SF, in the anticipation it may one day become waste). Somewhat bluntly summarized, the Belgium case of cat. B & C waste displays an ambiguous socio-technical combination of on the one hand highly specialized, advanced and focussed RWM research, and on the other hand rather impassive, fragmented and lagging RWM policy making. The issue has been and continues to be in a dedicated research phase, for over 40 years now. Up until today, the focus has been on scientific advance with regard to GD in Boom clay, based on the URL located in the municipality of Mol. The advanced technical knowledge and know how is recognized among the international research community, yet remains rather isolated vis-à-vis society and politics. Although from time to time parliamentary questions have been asked about the long term management of long-lived and high level waste and N/O recently made an effort to involve a broader range of stakeholders and civil society in the framework of the Waste Plan, many observers agree that in general this problem is characterized by a lack of societal involvement and political interest and commitment (Barbé, 2004; Bergmans en Van Steenberge, 2006; Laes et al., 2007; Laes and Bombaerts, 2008). Overall, orchestrated public debate

[54] On www.deredactie.be, 11/01/12 (Accessed: 11/01/12)
[55] See http://myrrha.sckcen.be/en/MYRRHA/Applications. (Accessed: 10/03/12)

about cat. B & C waste seems to be difficult up until today, and spontaneous public debate seems to automatically focus either on anti-nuclear discourse or on panic-like reactions from potential local stakeholders, i.e. communities with a 'sufficiently deep and elaborate' Boom clay geology, or their neighbours.

One could state that, in comparison to technical research, social aspects thus seem to have received unequal dedicated attention. We nevertheless tried to take 'social aspects' beyond the issue of participatory processes, and to reveal the underlying social assumptions that directly and indirectly color RWM as it has been and is being developed throughout what seem to be in first instance predominantly technical solutions. Throughout the second section we aimed to do so firstly by elaborating upon the connection between responsibilities, waste characterisation and inventory making, and technical options. Subsequently we explored what we refer to as more specific socio-technical challenges in a more dedicated manner. An in our opinion pregnant challenge related to all the topics treated (R&R, monitoring and controllability, knowledge and memory preservation and debates about advanced technologies) is how to harmonize the accompanying debates with the core socio-technical rationale of GD, namely the choice for a disposal method that is both final and passive, underpinned by not foreseeing future uses for the waste on the one hand and by not relying on future human action on the other hand.

List of Abbreviations

BS	:	Belgian law gazette
EURIDICE	:	European Underground Research Infrastructure for Disposal of nuclear waste In Clay Environment
FANC / AFCN	:	Federal Agency for Nuclear Control
FLT	:	Fund for the Long-Term management of radioactive wastes
GD	:	Geological Disposal
HADES	:	High-Activity Disposal Experimental Site
HLW	:	High Level Waste (abbreviation used to refer to high level and / or long lived waste)
KBS	:	King Baudouin Foundation
LILW	:	Low and Intermediate Level, short lived Waste
N/O	:	National Institution for the Management of Radioactive Waste and Enriched Fissile Materials
NPP	:	Nuclear Power Plant
R&R	:	Retrievability and Reversibility
RW(M)	:	Radioactive Waste (Management)
SAFIR	:	Safety Assessment and Feasibility Interim Report
SCK•CEN	:	Belgian Nuclear Research Centre
SEA	:	Strategic Environmental Assessment
URL	:	Underground Research Laboratory

References

Official, national science-policy documents

Belgisch Staatsblad. Available in Dutch from http://www.ejustice.just.fgov.be/doc/rech_n.htm. Date accessed: 16/02/12.

Delcroix, L. (1997). Vragen en Antwoorden - Senaat - *Le stockage des déchets radioactifs. De berging van radioactief afval*. Belgian Senate, 14 January 1997 (1767, nr. 1-36) 13.12.1996, 105.

Evaluation Commission SAFIR (1990). *End report*. State Secretary for Energy, Belgium.

FANC (2003). *Kingdom of Belgium. First meeting of the Contracting Parties to the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management*. *National Report.*

FANC (2011). *Resultaten publieksconsultatie mbt voorgestelde regelgeving (KB) voor eindberging radioactief afval*. Available online in Dutch from http://www.fanc.fgov.be/nl/news/resultaten-publieksconsultatie-mbt-voorgestelde-regelgeving-kb-voor-eindberging-radioactief-afval/377.aspx. Date accessed: 16/02/12.

NIRAS / ONDRAF (1989). *SAFIR – Safety Assessment and Feasibility Interim Report. 22.05.1989*. N/O, Brussels.

NIRAS / ONDRAF (2001a). *SAFIR 2 – Safety and Feasibility Interim Report 2*. NIROND 2001-06 E. N/O, Brussels.

NIRAS / ONDRAF (1999). *Het beheer op lange termijn van het laagactief en kortlevend afval. Samenvatting van de informatiedag over de lokale partnerships die NIRAS op 16 december 1998 organiseerde*. N/O, Brussels.

NIRAS / ONDRAF (2001b) *Towards a sustainable management of radioactive waste. Background to the SAFIR 2 report.* NIROND 2001-07E. N/O, Brussels.

NIRAS / ONDRAF (2001c) *Towards a sustainable management of radioactive waste. Background to the SAFIR 2 report. Press File.* 4 February 2002. N/O, Brussels.

NIRAS / ONDRAF (2008). *Duurzaam en veilig beheer van radioactief afval. Het nieuwe afvalplan belangt ons allen aan.* Eerste aankondiging B – Versie 3.3 – 13/11/08. N/O, Brussels.

NIRAS / ONDRAF (2011a). *Afvalplan voor het langetermijnbeheer van geconditioneerd hoogradioactief en / of langlevend afval en overzicht van verwante vragen.* NIROND 2011-02 N. Available online in Dutch from http://www.niras-afvalplan.be/nieuw/htm/getpage.php?i=1. Date accessed: 17/02/12.

NIRAS / ONDRAF (2011b). *De wettelijke procedure betreffende het Afvalplan is afgesloten. NIRAS Afvalplan – E-zine.* Available online in Dutch from http://www.niras-afvalplan.be/nieuw/web/ezines/news_nov2011_Niras_nl.html. Date accessed: 17/02/12.

NIRAS / ONDRAF (2011c). *Executive Summary of the Waste Plan for the long-term management of conditioned high-level and/or long-lived radioactive waste and overview of related issues*. NIROND

2011-04 E. Available online from http://www.niras-afvalplan.be/nieuw/htm/getpage.php?i=1. Date accessed: 17/02/12.

NIRAS / ONDRAF (2011d). Verklaring betreffende het Afvalplan ter uitvoering van de wet van 13 februari 2006. Afvalplan voor het langetermijnbeheer van geconditioneerd hoogradioactief en/of langlevend afval en overzicht van verwant vragen. NIROND 2011-03 N. Available online in Dutch from http://www.niras-afvalplan.be/nieuw/downloads/pdf/Afvalplan%20-%20verklaring.pdf.

Resource Analysis, Technum, Tractebel Engineering NV (2010). *Strategic Environmental Assessment (SEA) over het Afvalplan van NIRAS – Hoofdrapport.* Produced by Resource Analysis in order of N/O.

Verwilgen (2004). Brief van de voogdijminister van NIRAS aan NIRAS, Dossier langetermijnbeheer afval van de categorieën B en C, MV/DO/19.11.04-017276, 19 november 2004.

Other national references

ACW / ACV (2010). Wordt de Kempen een echt nucleair kerkhof? Interview with Mon Verrydt, ACW secretary in *Visie*, September 2010, redactie Kempen, Turnhout.

Barbé, L. (2004). *Kernenergie in de Wetstraat. Dissectie van de deals*. Internetbook, available from: http://www.lucbarbe.be. Date accessed: 16/02/12.

Bergmans A. (2005). *Van 'de burger als beleidssubject' naar 'de burger als partner': de Belgische queeste naar een lange-termijnoplossing voor het beheer van het laagradioactief en kortlevend afval*. Doctoral thesis, Universiteit Antwerpen, Faculteit Politieke en Sociale Wetenschappen, Antwerp.

Bergmans, A., Van Steenberge, A., Verjans, G. (2006). CARL Country Report – Belgium.

Bernier, F. (2011). *The strategic importance of URLs from a regulatory point of view.* FANC presentation at "HADES, 30 years of underground research laboratory", organised by ONDRAF/NIRAS, ESV EURIDICE GIE and SCK•CEN, 23, 24 & 25 May 2011, Antwerp, Belgium.

Bombaerts, G. and Eggermont, G. (2009). Afval beheren en controle loslaten. Over participatie bij berging van nucleair afval. *Oikos*, 48 (1), p. 28 – 38.

Dialogue Learning Centre (DLC) (2009). *Rapport Maatschappelijke consultatie "Beheer op lange termijn van hoogactief en langlevend radioactief afval*" — A consultation organised by N/O, spring 2009. Available in Dutch from: http://www.niras-afvalplan.be. Date accessed: 16/02/12.

Eeckhout, S. (2011). *Increasing the societal process for the programme for B&C waste*. Presentation given at the 17th Exchange Meeting organised by EIG EURIDICE on the Status of the long-term management of RW in Belgium: The cAt project in Dessel and the Waste Plan for B&C waste. Held at SCK•CEN, Mol, 7 December, 2011.

Glorieux, E. (2011). Belgium: next nuclear domino to fall. *Nuclear Monitor*, December 23, 2011, No. 739. Wise, Amsterdam.

Hilderson, E. (2009). *De regulering van de nucleaire activiteit*. Master thesis, Faculty of Law, University of Gent.

Koning Boudewijnstiching (2010a). *Publieksforum "Hoe beslissen over het langetermijnbeheer van hoogradioactief en langlevend afval?", eindrapport*. KBS, Brussels.

Koning Boudewijnstichting (2010b). *Publieksforum "Hoe beslissen over het langetermijnbeheer van hoogradioactief en langlevend afval?", eindverslag.* KBS, Brussels.

Laes, E., Chayapathi, L., Meskens, G., Eggermont, G. (2007). *Kernenergie (on)besproken. Geschiedenis van het maatschappelijk debat over kernenergie in België.* Acco, Leuven / Voorburg.

Laes, E., Schröder J., Meskens G. (2008). *CIP Research Brief Theme 2, Belgian case study: local partnerships for the siting of a LILW repository.* Community Waste Management (COWAM) In Practice (CIP). EC, FP6. Available from: http://www.cowam.com/?-Public-Deliverables-. Date accessed: 16/02/12.

Laes, E. and Bombaerts, G. (2008). In de klei rijden of democratiseren? Uitdagingen voor het nucleair afvalbeheer in België. *Samenleving en politiek*, 15 (8), p.30 – 38.

Lalieux, P. (2012). *The Waste Plan for Long-Term Management of HLW and/or Long-Lived Waste: Objectives, Process and Conclusions.* Presentation given at the 17th Exchange Meeting organised by EIG EURIDICE on the Status of the long-term management of RW in Belgium: The cAt project in Dessel and the Waste Plan for B&C waste. Held at SCK•CEN, Mol, 7 December, 2011.

Lalieux, P. and Van Geet, M. (2011). *The future roles of HADES URL in the Belgian geological disposal programme*. ONDRAF/NIRAS presentation and abstract, "HADES, 30 years of underground research laboratory", session 7, organised by ONDRAF/NIRAS, ESV EURIDICE GIE and SCK•CEN, 23, 24 & 25 May 2011, Antwerp.

Minon, J.P. (2012). *Reacties op het Ontwerp van het Afvalplan van N/O*. Presented at MONA, 06/03/12, Mol.

MONA (2005). *MONA, een weg naar de aanvaardbaarheid van een berging van categorie A-afval in Mol?* Geïntegreerd eindrapport. MONA, Mol.

STOLA (2004). *Het Belgisch laagactief en kortlevend afval: Thuis in Dessel? Een geïntegreerd bergingsproject met een technisch en maatschappelijk luik*. STOLA, Dessel.

Turcanu, C., Perko, T., Schröder, J. (2011). *The SCK•CEN Barometer 2011 - Perception and attitudes towards nuclear technologies in the Belgian population*. SCK•CEN-BLG-1082. SCK•CEN, Mol.

Weyns, W. (2010). *Definitieve berging van hoogradioactief en / of langlevend kernafval in een kleiformatie in de Belgisch-Nederlandse grensstreek*. Written for Greenpeace Belgium and Greenpeace the Netherlands. Michel Genet, Brussels.

International references

IAEA (1989). *Safety Principles and Technical Criteria for the Underground Disposal of High Level Radioactive Wastes*. IAEA Safety Standards: Safety Series No.99. International Atomic Energy Agency, Vienna.

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

OECD NEA (2001). *Reversibility and Retrievability in Geologic Disposal of Radioactive Waste. Reflections at the International Level*. Nuclear Energy Agency - Organisation for Economic Co-operation and Development, Paris.

OECD NEA (2003). *SAFIR 2: Belgian R&D Programme on the Disposal of High-level and Long-lived Radioactive Waste. An International Peer Review.* Nuclear Energy Agency - Organisation for Economic Co-operation and Development, Paris.

OECD NEA (2010a). *Nuclear Legislation in OECD Countries. Regulatory and Institutional Framework for Nuclear Activities – Belgium*. Available online from http://www.oecd-nea.org/law/legislation/belgium.pdf. Date accessed: 17/02/12.

OECD NEA (2010b). *Summarised responses to Retrievability and Reversibility (R&R) questionnaire issued to NEA member countries in May 2008*. Nuclear Energy Agency - Organisation for Economic Co-operation and Development, Paris.

OECD NEA (2011). *Reversibility and Retrievability (R&R) for the Deep Disposal of High-level Radioactive Waste and Spent Fuel. Final Report of the NEA R&R Project (2007-2011).* Nuclear Energy Agency - Organisation for Economic Co-operation and Development, Paris.

Wallace, H. (2010). *Rock Solid? A scientific review of geological disposal of high-level waste*. Written for Greenpeace International. GeneWatch UK consultancy report, Derbyshire.

World Nuclear Association (2012). *Nuclear Power in Belgium*. Available from http://world-nuclear.org/info/inf94.html. Date accessed: 17/02/12.

Interviews

- NIRAS / ONDRAF

Maarten Van Geet, 20/10/11, Brussels

- SCK•CEN

Geert Volckaert, 29/11/11, Mol

- FANC / AFCN

Walter Blommaert and Frederic Bernier, 07/12/11, Mol

- Greenpeace Belgium

Eloi Glorieux, 09/12/11, Brussels

- Directorate-General for Economy (FOD Economy)

Theofiel Van Rentergem, 16/12/11, Brussels

Annex 1

Overview of the estimated inventory and disposal dimensions.

The inventory of 2008 is based on the current nuclear programme, i.e. taking into account an exploitation time of 40 years of the current seven commercial reactors and the dismantling of all existing nuclear facilities. According to this inventory, the amounts of conditioned waste that N/O will have to manage between now and 2070 is estimated as follows:[56]

- Cat. A:
  69.900m³
- Cat. B:
  11.100m³ in the case of reprocessing
  10.430m³ without reprocessing
- Cat. C:
  600 m³ when all SF will be reprocessed
  4.500m³ when SF is considered waste

A life time extension of the three oldest reactors with ten years would influence the amounts as follows:

- Cat. A :
  70.900m³.
- Cat. B :
  11.220m³ in the case of reprocessing
  10.490m³ without reprocessing
- Cat. C :
  650 m³ when all SF will be reprocessed
  4.900m³ when SF is considered waste

Cat. A waste thus represents more than 80% of the total volume of conditioned waste, while cat. B & C account for more than 99% of the total activity.
N/O underlines that "these forecasts are likely to change in the future as they depend on numerous factors (release criteria, technologies, legal provisions) that are themselves liable to change with time".[57]

[56] See www.niras.be/nederlands/7.8_Inventaris_nl.html
[57] See www.niras.be/engels/7.8_Inventaris_eng.html

Annex 2

Indicative visualisation of the geological repository and the surface facilities envisaged for B & C waste (N/O, 2011c, p.15).

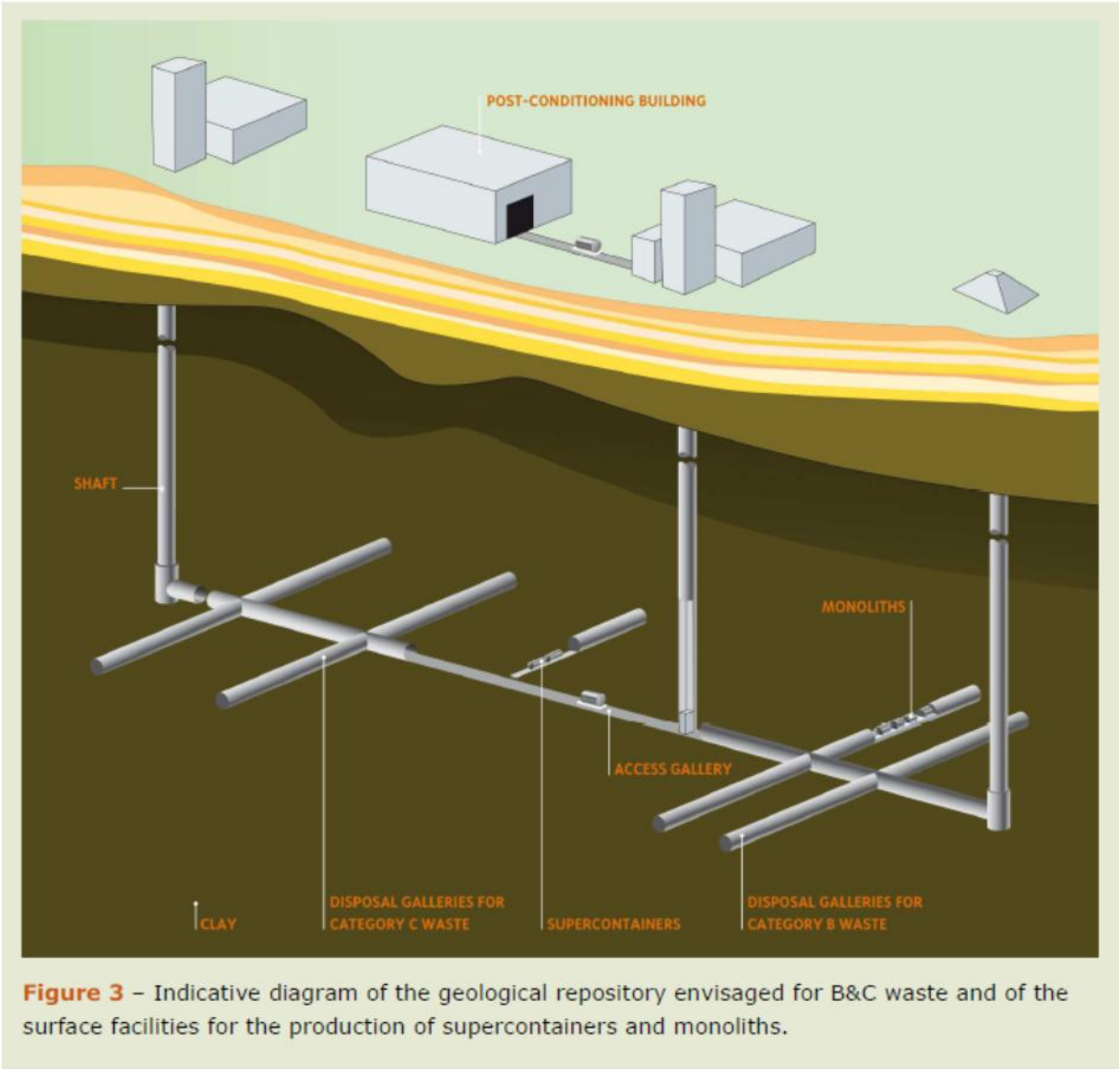

Figure 3 – Indicative diagram of the geological repository envisaged for B&C waste and of the surface facilities for the production of supercontainers and monoliths.