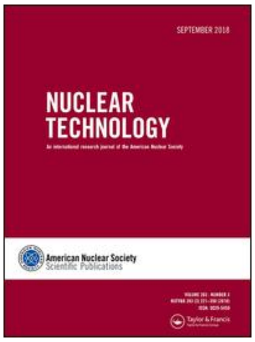

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# The Power and Limits of Classification: Radioactive Waste Categories as Reshaped by Disposal Options

Céline Parotte*

*University of Liège, Spiral Research Center, Research Unit Cité, Place des Orateurs (Quartier Agora) B31, 3/9, 4000 Liège, Belgium*

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**Abstract** — *How does naming an object affect the way it is or could be managed? This paper examines and compares classification systems for radioactive waste applied by the International Atomic Energy Agency (IAEA) and in France, Canada, and Belgium. I analyze how the relevant actors classify radioactive objects, and in so doing, prescribe their management. By comparing and describing four established classification systems, I highlight how the IAEA and national classification systems for radioactive waste systematically associate the "high-level radioactive waste" category with the "deep geological disposal" option. Building on Science and Technology Studies, I argue that creating categories of high-level radioactive waste does more than just describe different types of wastes: It also prescribes certain management options (e.g., deep geological disposal), thereby opening up certain options for action and closing down others. I underline how uncertainties remain about what to do with radioactive wastes in blurred, unstabilized categories that are classified and named differently by different actors. Examples of "blurred" categories include spent nuclear fuel from uranium oxide and spent nuclear fuel from mixed-oxide fuel. Should these categories be managed as a waste or as a resource? Should their common fate be the deep geological disposal? Revealing the power and limits of a top-down classification system to manage radioactive waste, I maintain that remaining uncertainties could reverse the dynamics of imagining a final long-term repository option for a given category. In the absence of stabilized categories, the deep geological disposal option becomes the primary mode of classifying objects as either waste or a resource. This analysis flips the conventional notion of high-level radioactive waste on its head: Instead of asking what management option should be preferred to deal with nuclear waste, the chosen disposal option has a decisive influence on what counts as radioactive waste in the first place. Nuclear engineers and top nuclear managers are invited to take a fresh look at the limits of their radioactive waste classification systems. They could potentially consider a new focus (the disposal option) and new allies (such as geological disposal designers, nongovernmental organizations, and civil society) to overcome them.*

**Keywords** — *Radioactive waste classification system, blurred category, high-level radioactive waste, deep geological disposal, comparative analysis.*

**Note** — *Some figures may be in color only in the electronic version.*

## I. INTRODUCTION

What is the difference between classical waste, radioactive waste, and a potential resource? Why does the International Atomic Energy Agency (IAEA) distinguish between spent nuclear fuel and radioactive waste? How does naming an object affect the way it is or should be managed?

Classification is a very common, formalized or tacit, unconscious or conscious activity that potentially concerns every kind of object and that can be very specific to each community.[1] The nuclear field has its own unique classification practices. Yet, despite common "standards," the classification systems of radioactive waste differ significantly from one country to another.

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*E-mail: celine.parotte@uliege.be

This paper scrutinizes the power, the limits, and the consequences of classification using a Science and Technology Studies (STS) perspective. As a political scientist, I rely on two theoretical insights commonly encountered in STS originally developed by Jasanoff[2] and by Bowker and Star.[3] Briefly, I first assume that the ontologies of waste [i.e., high-level radioactive waste (HLW) as it is managed] and its legitimate representation (HLW as it should be managed) are mutually constituted.[2] Second, that naming is a powerful action,[3] i.e., classifying things is not a neutral activity, but one that exerts and assigns power. Classification systems for radioactive wastes can be considered as instruments that frame the actions of actors and state what is (im)possible to do with a radioactive object—or waste. In this sense, they also reveal the nature of the relationships between the different actors involved in radioactive waste management (RWM).

With a focus on the power and limits of four radioactive waste classification systems (AIEA, France, Canada, and Belgium), the central argument of this paper is that defining what radioactive waste is depends on the views on how it should be managed and vice versa. Usually, the physical properties of waste affect the classification, which then informs the type of disposal option. However, problems occur when certain objects do not easily fit into existing categories, as uncertainties arise about what these objects really are and how they should be managed. I suggest that to deal with these "unclassified" radioactive objects, nuclear experts and engineers could focus first and foremost on the design of the long-term repository option. In the same vein as Lowenthal,[4] I maintain that the disposal site and its constraints could redefine the category of radioactive waste. Imagining what kind of radioactive objects a given design of a future deep geological disposal facility could accommodate could redefine the radioactive waste classification system.

The ambitions of this paper are both theoretical and empirical. It aims to bring existing theoretical reflections on STS into a productive conversation with current nuclear engineering management practices. Engaging with these theoretical insights, nuclear engineers, geological disposal designers, and top nuclear managers could to take a fresh look at their radioactive waste classification systems and practices, and at their consequences. Empirically, the aim of the description and comparison of the three different case studies is to identify the limits of the top-down national classification systems and to highlight the potential solutions some interviewees and theorists have already put forward to overcome them.

The methodology and theoretical sections of this paper detail the materials collected and how the case studies were selected, and summarize the key analytical STS elements I have mobilized with concrete examples related to nuclear waste classification systems. In these sections, I explain how radioactive waste classification systems embody the same characteristics as any other classification system and face the same challenges. The empirical section is divided into two parts. In the first part, I describe and compare existing international and national nuclear classification systems to highlight the power of systems used to classify radioactive waste. In the second part, I describe the limits of such classification systems with a particular focus on objects that remain "unclassified" or fall into "blurred," "un-stabilized" categories [i.e., French mixed-oxide fuel (MOX), spent fuel, or Belgian spent fuel]. Finally, in the discussion I put forward Lowenthal's suggestion for the United States[4] and those of some interviewees with an engineering background on how to deal with the uncertainties related to unclassified radioactive objects. In the absence of stabilized categories, the deep geological disposal option could become the primary mode of classifying objects as either waste or resource.

## II. CASE STUDIES, DATA COLLECTION, AND ANALYSIS

Empirically, this paper analyzes the power and the limits of classification systems through four case studies: IAEA, France, Belgium, and Canada. The IAEA classification system remains relevant, as the General Safety Guides that describe the classification system represent an "international consensus on the highest level of safety for the protection of humans and the environment."[5] As the IAEA guidelines indicate what states can do in this domain, the evolution of the IAEA classification system offers an interesting illustration of the trends that occur in radioactive waste classification systems. The choice of the three other case studies selected is primarily based on the past research experience of the author on nuclear waste issues since 2010 (Ref. 6). The goal of this previous study was to compare long-term HLW management practices to underline how the public and experts inform (or not) the deep geological disposal design.[a] I selected the three nuclearized Western countries based on three criteria: (1) their respective RWM organizations all support deep geological disposal (with or without

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[a] This paper builds on and extends some of the author's previous reflections published in French on this topic in 2018.

reprocessing of spent fuel) as the main option to manage HLW, (2) the repository projects all face strong public opposition, and (3) the RWM organizations in these countries adapt their management practices to include the public and experts in different ways.[7] The added value of the descriptive comparison of the three national radioactive waste classifications systems is that it provides contrasts and reveals patterns that might otherwise remain unperceived.[8]

When designing the methodology, I decided to combine different qualitative methods to ensure in-depth analysis and the triangulation of primary and secondary data collection[9] (see Table I for an exhaustive summary).

As a political scientist aligned with the interpretivism paradigm, I adopted an inductive approach. At the earliest stage of the data collection, what exactly will be hosted in the deep geological disposal emerged as an important sociotechnical issue for some interviewees and a practical issue for engineers in charge of designing or assessing geological disposal. In order to analyze this issue in detail, I conducted a systematic thematic analysis[10] with thematic entry points that directly or indirectly pertain to the topic of radioactive waste classification systems: official reports and national legislation or safety guides that provide a complete description of them, as well as statements made by interviewees who expressed their opinions and concerns about what radioactive waste is (or is not), and several related issues concerning deep geological disposal and long-term management. Two limitations deserve to be mentioned and will hopefully inspire further research. First, the collected data and the analysis do not include the emergence of waste classification from a historical perspective but rather present them in their current manifestation. Second, interviews with the members of IAEA who were responsible for writing the Safety Guides and those who took part in the first technical report in 1970 on the topic could help understand why the countries saw it appropriate to develop their own systems and the effective role that the IAEA could play in harmonizing those systems.

Last, this paper is structured according to the analytical perspectives of Bowker and Star[3] and of Jasanoff[2] (see Sec. III). The results of the case studies are provided to illustrate a theoretical argument (the importance of considering the power and the limits of radioactive waste classification systems) but also have a pragmatic purpose (to identify existing problems with current classification systems). These descriptions aim to support the proposals that I provide in the discussion section on how to overcome the limits of the radioactive waste classification system.

## III. ANALYTICAL PERSPECTIVE: THE POWER AND LIMITS OF CLASSIFICATION

To examine the work of practitioners in nuclear organizations and federal departments in charge of managing and controlling HLW, it is useful to think about classification in a way different from that usually used by nuclear engineers. I have structured the argument around a set of theoretical insights commonly found in STS studies (developed by Jasanoff[2] and by Bowker and Star[3]) that help to better understand the power and the limits of radioactive waste classification systems. These insights can be summarized as follows:

1. High-level radioactive waste as it currently is and high-level radioactive waste as it should be managed are mutually constituted.

2. Classifying objects is a dynamic activity to manage particular situations and is useful in many ways.

3. Every classification system reflects imperfect choices, tensions, and limitations.

4. In particular, some objects that do not belong in preexisting categories are assigned to a “blurred category.” Closer attention to these objects helps to better understand the power and the limits of the current classification system.

The first theoretical insight is to consider that radioactive waste as it is and radioactive waste as it should be managed are mutually constituted. To paraphrase Jasanoff, they are produced together. In Jasanoff’s words, considering government practices on RWM as coproduced means that “the way in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it.”[2] The following empirical sections provide concrete illustrations that the ways in which radioactive wastes are managed are inextricably linked with what radioactive waste is, in multiple and complex ways.

The second theoretical insight relies on why classification systems matter. In many areas, classification systems are seen as one of the essential elements in managing a situation, a problem, or an activity. These classification systems are used in different ways. First, they organize collective memory[1] by highlighting as well as hiding, and they impose a way of reading reality by stressing what is relevant to remember. Second, STS studies have shown that beyond the production of knowledge, classification systems enable administrative action and cooperation between different actors “across different social worlds.”[3] They make it possible to distribute skills to specific administrative

TABLE I

Type of Data Collected to Understand IAEA, France, Belgium, and Canada

| Type of Data Collected for this Paper | IAEA | France | Belgium | Canada |
|---|---|---|---|---|
| Primary data: 87 semistructured interviews | – | 32 interviews, (13) with local committee actors in 2014 and 2018, but also with national representatives from consultative bodies (7), safety authorities (4), HLW experts (3), journalists (2) and the ANDRA (3). | 38 interviews with the ONDRAF/NIRAS (21), safety authorities (6), waste producers (6), HLW experts (3), and the administrations concerned (2) between 2012 and 2019 | 17 interviews with local committees (8), safety authorities (1), federal consultative bodies (2), policy makers (2), the Nuclear Waste Management Organization (2), and HLW scientists (2) in 2015 |
| Primary data: participatory observations | – | Observations at Bure (2014, 2018) the expected future site of HLW | Observations at the Société Belge de Géologie de l'Ingénieur et de Mécanique des Roches or SBGIMR workshop on "High-Level Radioactive Waste Disposal" (2019) | Observations at Manitouwadge, Nipigon, Schreiber, and Ignace (2015), potential sites for HLW at the time |
| Secondary data | Technical reports and safety guides (1970 onward) (15) | National legislations, official reports of federal/national administrations, official websites and reports by RWM organizations, regulatory bodies, local information committee reports and websites, press archives, and recent R&D developments on geological repositories. | | |

services,[11] to "usefully" centralize large-scale governmental or industrial activities, or to improve "administrative control."[12] Third, the form of classification and names given to the categories—when they are "simple and easy to understand"[13] and when they appear "in good prototypical fashion, look and feel scientific"[3]—facilitate communication between experts from different countries, but also between experts, waste producers and managers, and the general public.[13] Fourth, the implementation of the classification system directly influences the actors who "mold their behavior to fit those conceptions."[3] As noted by Bowker and Star, these categories impose themselves on actors who cannot escape them and consequently modify their behavior accordingly. Classification coordinates include and exclude. Classification becomes an "integral part of the organizational structure," a "political actor" in its own right that distributes power.[3]

The third theoretical STS insight stresses that the classification system is always the result of a continually renegotiated imperfect compromise.[3] Bowker and Star maintain that in any classification system, there is a permanent tension that raises the question: To what degree of detail does one collect and classify objects? A classification system is supposed to be based on consistent and operational classification principles, to suggest mutually exclusive categories and be able to provide "total coverage of the world it describes."[3] However, for several reasons related to the object, the person who applies it, or changing practices, in reality, no classification system can meet these three characteristics. In some cases, those in charge of applying the classification systems may disapprove of them, ignore them, interpret them differently, or even adopt routine behaviors that blend different and contradictory principles.[3] For instance, STS authors explain that the completeness of the classification system is sometimes deliberately ignored for financial reasons: An anomaly may be detected but not taken into account because it is too expensive—politically or bureaucratically—to be included it in the registers of classification.[3] This question seems to arise, for example, with a certain type of Belgian waste [Naturally Occurring Radioactive Materials (NORM) and Technologically Enhanced Naturally Occurring Radioactive Materials (TE-NORM) ]. In other cases, from a practical point of view, it may be impossible to allocate an object to only one category given the disagreements surrounding its categorization or even the ambivalence of the object concerned.

In line with the limits of classification systems, the fourth theoretical insight stresses that, in practice, some objects make certain categories permeable. Bowker and Star speak of "blurred categories"[b] created by "boundary objects":

> Blurring categories means that existing differences are covered up, merged, or removed altogether; while distinctions construct new partitions of reinforcement of existing differences. This mutual process of constructing and shaping differences through classification systems is crucial in anyone's conceptualization of reality (…).[3]

Such boundary objects are interesting for a nuclear engineer to explore as they reveal some of the limits of classification systems. They highlight the issues related to the coexistence of different uses or interpretations of the same object and the difficulty of assigning it to one particular category. In other words, a boundary object challenges the classification system; it blurs the limits of existing categories or creates "unstabilized" categories. A boundary object also allows "different groups to work together without prior consensus"[14]; different dynamics are at work depending on the uses of the object. In other words, what makes an object a boundary object does not depend on the inherent qualities of the object. A boundary object is first and foremost defined through the actions of groups and individuals with respect to the object. In the empirical sections, I discuss how spent fuel can be considered as a boundary object in Belgium because it is sometimes regarded as a recoverable material and sometimes as a waste. It is what its producers intend to do with spent fuel in the short and long term that defines the different scenarios and allows the action or inaction of other actors.

The following empirical sections are presented in two parts. After a brief summary of the current national radioactive waste classification systems in Belgium, France, and Canada, the first part of the empirical section presents the power of a radioactive waste classification system and stresses how, despite their differences, all four of these classification systems aim to systematically associate one particular category of waste with one particular management option. The second part scrutinizes the limits of the current radioactive waste classification systems with a focus on the case of spent fuel.

## IV. THE POWER OF RADIOACTIVE WASTE CLASSIFICATION SYSTEMS

First, radioactive waste classification systems order the radioactive objects that exist in a territory in a particular way. Belgium, France, and Canada are all IAEA member states, and to varying extents, draw on the IAEA's proposed

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[b] The concept of blurred category should not be confused with the residual category, which is a category per se in the current national radioactive waste classification system (mostly called "other").

classification system, to which they add their national specificities (see Table II). First, the number of categories proposed and the source of radioactive waste[c] differ from one country to another. In Canada, there are four categories of radioactive waste: low-level radioactive waste (LLW), intermediate-level radioactive waste (ILW), HLW, and waste from uranium mines and mills.[16] In France, there are six official categories: (1) very short-lived waste (VTC), (2) very low-level waste (TFA), (3) short-lived low- and medium-level waste (FMA-VC), (4) low-level long-lived waste (FA-VL), (5) long-lived intermediate-level waste (MA-VL), and (6) high-level waste (HA-VL). In Belgium, there are officially three categories: low-and-medium-level short-lived waste (called category A waste), low-level-and-medium-level long-lived waste (category B waste), and high-level short-lived-and-long-lived waste (category C waste). Second, each state has its own nuclear legacy waste (also called Déchets de stockage historique or DSF in France or déchets historiques in Belgium), which is subject to long-term management in its own right. In Canada, this is the case for legacy waste produced by Canadian research laboratories and the National Research Council from 1944 onward.[17] In Belgium, this is also the case for legacy waste resulting from the decommissioning of former Eurochimic facilities (called BP1), former installations of the waste department of the Belgian nuclear power plant (NPP) laboratory (called BP2), Belgonucléaire, the former Belgian MOX fuel manufacturing plant, the legacy management of the National Institute for Radioelements, and Best Medical Belgium SA. They are the subjects of a full inventory. In France, 23 "disposals of legacy waste" are listed in the inventory of the waste manager.[18]

Building radioactive waste classification systems and the regulation of safety are first and foremost a national responsibility.[19] In this sense, the IAEA General Safety Guides have no regulatory power over national RWM classifications systems, and therefore can only issue guidelines and recommendations in this area. From a legal point of view, research and development (R&D) and the regulation of nuclear materials and activities (including waste) are the responsibility of federal jurisdictions in Canada and in Belgium, and of national jurisdictions in France. It is therefore the federal or national government that formulates the necessary policies, regulations, and monitoring mechanisms specific to the nuclear sector, and more specifically, its categorizations. In Belgium, for instance, several actors can influence the Belgian radioactive waste category system. The national safety authority [the Federal Agency for Nuclear Control (AFCN)] has the power to define what is a radioactive material and what is not. The AFCN is responsible for defining the boundaries of the classification of substances falling into the classification of radioactive substances for special management. The producer of the radioactive object and the Belgian federal government can decide if the radioactive source should be considered as a waste or resource, while the powers of the Belgian RWM organization [the federal public interest organization the National Agency for Radioactive Waste and Enriched Fissile Material (ONDRAF/NIRAS)] are restricted to issues related to waste acceptance criteria somewhere at the end of the cycle. Among others, the ONDRAF/NIRAS has the competence to establish quality management criteria for radioactive waste but the organization is strongly dependent on other actors' decisions. It is only when they declare their radioactive object to be waste that the ONDRAF/NIRAS can effectively intervene. The competencies are then distributed differently depending on the status and the name given to the objects.

Second, the radioactive waste classification system is considered a prerequisite for the development of a strategy to manage these wastes.[19] They have many significant consequences including influencing technical strategies or providing information on short- and medium-term energy scenarios.[18] They affect the type of management solution suggested,[20] the technological design, the size of the repository, the processing of the waste and the length of time the waste will need managing,[13] the economic and geological dimensions of a management project,[16] and the volumes to be considered.

Third, the dynamics of radioactive waste classification systems tend to reinforce a particular way of managing the waste.[d] The evolution of the IAEA categorization of radioactive waste[e] provides an interesting illustration. To date, the international system for the categorization of radioactive waste has undergone three revisions. The first

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[c] For example, Canada is one of the largest suppliers of uranium in the world, supplying 22% of the world's natural uranium in 2017 (behind Kazakhstan 39%) (Ref. 15). Canada therefore has to manage waste from mines and uranium extraction and concentration plants (that are a category of waste in their own right), which is not the case in France and Belgium.

[d] Even in an inspection of the form of waste classification, the IAEA suggests that its member states change the terminologies of the categories of radioactive waste already accepted "as little as possible."[13]

[e] The IAEA safety standards distinguish two classification systems: the categorization of radioactive sources and the categorization of radioactive waste. Here, I focus on the second categorization system.

TABLE II

Comparison of the Current National Nuclear Classification Systems in Belgium, France, and Canada

|  | Belgium | France | Canada |
|---|---|---|---|
| Number of defined categories | 3 categories | 6 categories | 4 categories |
| Classification according to half-life and level of activity | A (equivalent LLW IAEA 2009); B (equivavlent ILW IAEA 2009); C (equivalent HLW IAEA 2009) | VTC (equivalent VSLW IAEA 2009); TFA (equivalent VSLW IAEA 2009); FMA-VC (equivalent LLW IAEA 2009); FA-VL (equivalent VLLW IAEA 2009); MA-VL (equivalent ILW IAEA 2009); HA-VL (equivalent HLW 2009) | LLW (equivalent IAEA 2009); ILW (equivalent IAEA 2009); HLW (equivalent IAEA 2009) including spent fuel; mining waste related to uranium treatment |
| Temporal classification | Distinction made between current and legacy waste | Distinction made between current and legacy waste | Distinction made between current and legacy waste |

publication in 1970 was the outcome of a panel meeting on Standardization of Radioactive Waste Categories held in Vienna from November 6 to 10, 1967. The purpose of the first version was twofold: first, to produce a “standard to be used as a common language between people working in the field of waste management at nuclear installations” and to “act as a practical tool for increasing efficiency in communicating, collecting and assessing technical and economical-(sic) information (…).”[21] The original 1970 proposal was revised in 1981, 1994, and 2009 for two main reasons. The first concerns one of the three characteristics of any ideal classification system: its completeness [“the classification scheme developed previously (…) does not cover all types of radioactive waste”].[19] The second, particularly important in our case, is the need to link the suggested classification system to a particular end-use of the object.[19] In other words, each category is related to a particular “disposal option.” The IAEA considers this classification system as “a widely used qualitative classification.”[13] It distinguishes it from so-called “natural” classification systems (the agency itself emphasized this qualification by placing it in inverted commas) which is based on the origin of the waste and its physical state (liquid, gaseous, or solid). Finally, the borders of the classification system also emerge by distinguishing what is excluded from it. This is the case of spent fuel “whether spent fuel is considered as resource (with the application of reprocessing – nationally or internationally (…) or whether it is intended to return spent fuel to the supplier”[22] and for the exempt waste with “sufficiently low in activity concentration to satisfy the regulatory requirements for exemption/clearance (…).”[22]

In practical terms, the criteria for the classification of radioactive waste are based on the level of activity of the waste, its radiotoxicity, and thermal energy.[13] On the basis of these criteria, the IAEA changed from four major categories of waste in 1970, 1981, and 1994 to six categories in 2009. Originally, the categories were exempted waste, HLW, ILW, and LLW. In 1994, an additional distinction was made between low- and medium-level radioactive waste depending on the lifetime (“half-life” or “period”) of the waste. Waste can be short lived or long lived. A new criterion was therefore integrated into the classification system. The half-life thus determines both the level of activity and the solutions that are to be implemented for long-term management.

In the additional considerations of its report (1994), the IAEA classification system was described as being as inclusive as possible. It recognized that other wastes based on additional criteria such as long-lived natural radionuclides could exist.[13] The boundaries of a category are defined according to what it is not, but the existence of a residual category makes it possible to ensure the completeness of the proposed classification system. The characteristics of “other” waste are “sufficiently different” from the main types of waste to require an “individual regulatory approach.”[13]

Last, the IAEA can provide additional details to support a particular purpose. In 2009, the classification became even more precise for LLW, which was further subdivided into three types: very short-lived waste (VSLW), very low-level waste (VLLW), and LLW. A specific solution was recommended for each type of waste. Compared to its classification in 1994, the waste categorization undertaken by the IAEA in 2009 went a step further (see Figs. 1 and 2, which show the IAEA changes). More than ordering the object, categorization influences the type of management of the object. For example, HLW is associated with the

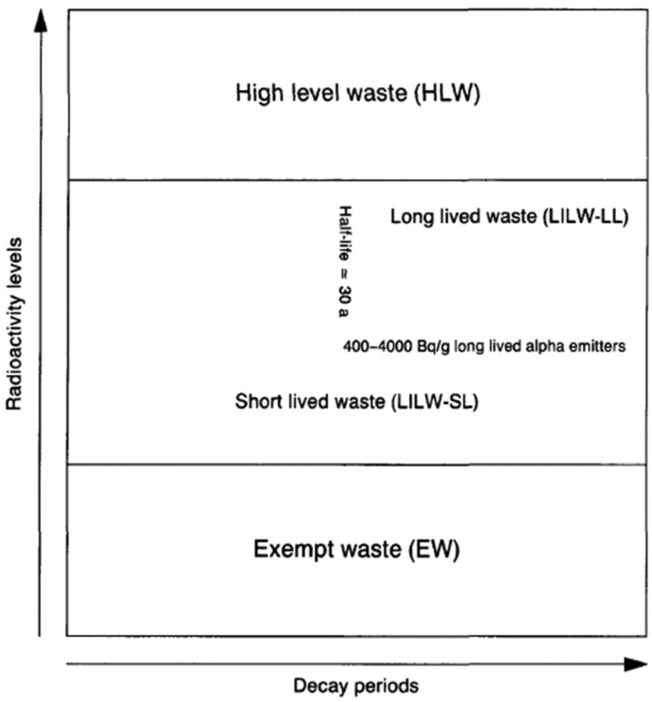

Fig. 1. International Atomic Energy Agency Classification of Radioactive Waste Safety Guide, Safety Series No. 111-G-1.1 (1994) (Ref. 13).

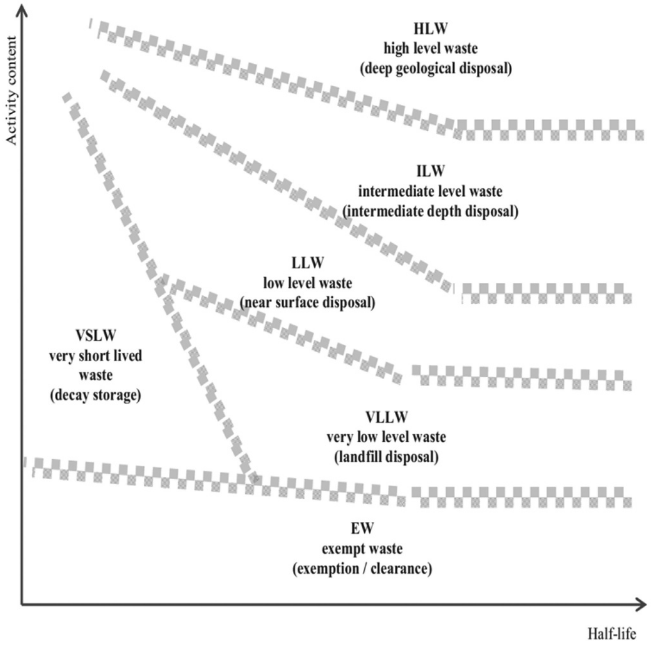

Fig. 2. International Atomic Energy Agency Classification of Radioactive Waste, IAEA Safety Standards Series No. GSG-1 (2009) (Ref. 22).

geological repository while LLW is associated with surface management solutions.

In the same vein, each existing category of the national radioactive waste classification systems in Canada, France, and Belgium is associated with a particular management option (see Table III). In particular, the categories of long-lived and high-level radioactive waste (categories B and C in Belgium, MA-VL and HA-VL in France, and HLW in Canada) tend to be systematically associated with the deep geological disposal option.[f][23]

However, there are also some limits to these national radioactive waste classification systems. As I discuss in Sec. V, each limit highlights a series of uncertainties in long-term management scenarios and reveals the political and economic implications of waste categorization.

## V. LIMITS OF THE RWM CLASSIFICATION SYSTEM AND ITS CONSEQUENCES

### V.A. Dealing with Blurred Categories

The IAEA specifies that ideally, a classification system should cover all types of radioactive waste but should also ensure that it remains sufficiently “flexible to serve specific needs.”[13] The IAEA also acknowledges the limits of its proposed classification of waste: “The boundaries between the classes are not intended to be seen as hard lines, but rather as *transition zones* [italics added by the author] whose precise determination will depend on the particular situation in each State.”[19]

The choices made by the national classification designers also reveal anomalies, unclassifiable, “marginal” or “indefinite” objects. Several are identified in Table IV. To get around the limits of existing categories, the objects are generally included in the residual category “other.” This has been the case of the IAEA classification since 1994 (see Sec. IV) and also in France and in Belgium. In France,

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[f] The French and the Canadian governments have already validated deep geological disposal as the long-term option. The site selection process launched in 2010 by the Canadian waste management agency is still ongoing. Two communities are still in the running to host the final repository. In France, the process of siting deep geological disposal (called the Cigeo project) is the most advanced European programs after those of Finland and Sweden. An area has already been identified, and the first industrial operations are planned for 2025 (Ref. 20). Belgium is a special case in this respect because the successive governments have not yet reached a decision in favor of one or other long-term management options for this type of waste. However, since 2011, the Belgian RWM organization (ONDRAF) has clearly shown its preference for deep geological disposal in clay for this type of waste.

TABLE III

Specificities of the National Nuclear Classification System in Belgium, France, and Canada

| | Belgium | France | Canada |
|---|---|---|---|
| Combination of categories for management purposes | Category A full-fledged project; categories B and C managed together | TFA, FMA-VC categories managed together; category FA-VL; MA-VL, and HA-VL categories managed together (the Cigeo project) | Mining waste: full-fledged project; LLW and ILW categories managed together; HLW: full-fledged project (the Adaptive Phase Management project) |

TABLE IV

Blurring Categories (When These Exist) in the National Nuclear Classification System in Belgium, France, Canada

| | Belgium | France | Canada |
|---|---|---|---|
| "Blurred categories" in the sense of Bowker and Star | NORM, T-NORM; radium-bearing waste;<br>waste for future remediation; spent fuel; spent fuel MOX | NORM; waste without a waste stream " filières"; residues left over from uranium mines; spent fuel MOX | – |

in addition to the six categories, there is a category named "other." The French RWM organization, the National Agency for Radioactive Waste (ANDRA), explains that the category "other" refers to registered waste that has physical and chemical characteristics unsuitable for the six categories mentioned previously.[g] This category includes waste containing NORM, residues left over from uranium mines, and waste lacking a specific disposal solution (called waste without a waste stream "Déchets sans filière"). In Belgium, in addition to the three categories, the Belgian RWM organization also identified four types of waste not included in the three above-mentioned categories, placed in the category "other" given their specific properties. These are radium-bearing waste (containing greater or lesser quantities of radium), NORM, TE-NORM (very low-level radioactive but long-lived waste present in a certain number of industrial sites not subject to a nuclear license), and future unidentified radioactive waste (resulting from future site remediation associated with decommissioning).[24]

By taking into account the differences and peculiarities that characterize them, the objects classified as "other" reinforce or weaken and constantly challenge the existing classification and its limits. National actors responsible for creating or applying the classification are fully aware of the importance of such constant redemarcation of boundaries. This is, for instance, the case of any radioactive object at the boundary of the predefined category of a radioactive waste classification system:

> When we get closer to the limit, where exactly are we located, where is this limit? Then, we can put something on paper because it is always easier to classify things, but we must be aware that this limit will change" (ONDRAF employee with engineering background talking about the differences between Belgian radioactive wastes in a 2014 interview translated from French by the author).

[NORM waste, TE-NORM] waste appears at the boundaries, at the limits of …. This is the problem of natural waste and this is a Pandora's box" (Belgian federal administrative employee with a background in nuclear engineering in a 2014 interview translated from French by the author).

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[g] As ANDRA mentions on its website, "waste without a waste stream *filière* (DSF) is intended to integrate one of the six categories possibly after treatment or characterization" [in the ANDRA "inventory" at https://www.andra.fr/les-dechets-radioactifs/tout-comprendre-sur-la-radioactivite/inventaire (accessed March 10, 2020)].

Another challenge for current national radioactive waste classification systems concerns the objects whose status remains uncertain. Spent fuel is a particularly interesting case as each country considers spent fuel differently, which could challenge the category of HLW. Is spent fuel considered as waste or as recoverable material? In Canada, there is no ambiguity. The 2002 Canadian Nuclear Fuel Waste Act[25] does not distinguish between spent fuel and HLW, but defines both as waste.[h] In France and in Belgium, however, (reprocessed) spent fuel can be considered as a blurred category in the sense of Bowker and Star.

In France, spent fuel is considered as a valuable resource. Here again, the category is clearly defined: Only the waste resulting from the reprocessing of the latter (vitrified waste and compacted waste) is considered highly radioactive.[18] Part of the spent fuel is therefore considered as waste, the other part as a recoverable material called MOX. According to the analysis of Dessus in France: "The concept of nuclear waste therefore does not refer to the dangerousness of the materials in question, nor the time of presence of these materials on national soil, but only to whether or not they can be recycled."[18] Once the MOX fuel is reinserted in an NPP, the status of the used MOX becomes unclear. According to a former director of the ANDRA, this is where the strongest ambiguity lies: "What should they do with MOX fuel once it has been used?"

The status of spent fuel is less clear in Belgium. Partially reprocessed,[i] depending on the owner of the radioactive source, the legislator/government, the regulatory body, and the public body in charge of waste management, under certain conditions and depending on its use, it can be considered as a recoverable material, and sometimes as waste. As summarized by a worker from one of the two Belgian NPPs, several uses are still possible:

> It [spent fuel] is no longer usable in the reactor core, it is stored but it is not clear what they [the producers] intend to do. Some say that they will send it back to The Hague, others that we will find a system to use it in nuclear power plants with higher performance cores. Still others say we will send it around the world, to Asia or elsewhere to use the residual power it still contains. At present, they really don't know (Belgian NPP worker in a 2014 interview translated from French by the author).

The position of Synatom, a private company that is a subsidiary linked to the nuclear industry in Belgium that is responsible for managing the entire spent fuel cycle in the territory, is very clear: Belgian spent fuel is potentially usable:

> We do not really like the term "waste." We should talk about spent fuel, because we can recover uranium and plutonium (…) I don't think Synatom should present a program A or B but, in my opinion, we can say that there is a logic to keeping an open door for reprocessing but for the moment, we continue to store it on-site and in this case the policy-maker must not decide (Belgian nuclear industry representative in a 2014 interview translated from French by the author).

## V.B. Consequences of Blurred Categories on Management Options

How should such blurred categories be managed? One of the consequences of the limits of radioactive waste classification systems and of the blurred categories is that they create additional uncertainties for the design and the development of management options.[27] Although the HLW category tends to be systematically associated with the deep geological option, including (or not) "spent fuel" in the "waste" category has concrete consequences for the deep geological disposal option.

First, in all the countries concerned and depending on the energy choices of the country, such classification decisions influence the volume to be deposited in the final repository. For instance, in Belgium, a geophysicist at the ONDRAF/NIRAS (2019) stressed: "Our design is closely linked to the actual waste inventory, this design can be modified depending on political conditions (including nuclear phase out or not)." Second, more specifically in France, the uncertainties associated with the management of particular objects such as MOX spent fuel increase the ambiguity about the exact type of waste that will be deposited in the deep geological disposal project. These uncertainties remain a public concern at both the national and local levels and were raised, among others, during the 2014 public debate on the deep geological disposal project[28] as explained by Dessus et al.:

> Very quickly, this public debate highlighted the ambiguity of the terms used and showed that it was

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[h] There are two hypotheses that it might be interesting to confirm in future research to explain the absence of blurred categories in Canada. The first relates to their energy policy choices. Canada does not reprocess its spent fuel (therefore it has no MOX spent fuel) and its policy is to classify its spent fuel as the HLW category. The second could be related to the greater inclusion of the two categories "LLW and Mining waste related to uranium treatment."

[i] Spent fuel was first reprocessed before the government decided on a moratorium on this subject in 1993 (Ref. 26). There is therefore both spent fuel and HLW from spent fuel in Belgium.

> necessary to broaden out the scope of the analysis to all dangerous nuclearized materials as the notion of "ultimate waste" seemed inadequate and reductive.[18]

At the local level, some members of the Local Information Committee (set up to monitor the project and inform the public) also expressed several concerns. They want guarantees and justifications concerning the origin of the waste, the type, and the particularities of waste that are allowed or forbidden in the repository:

> Storage in a deep layer [can be considered] under two conditions: they can't just deposit anything and everything, I will never forget this condition. […] and we will not begin to take packages from Latvia or small states that have a nuclear power plant (French Local Information Committee in a 2014 interview translated from French by the author).

The closer we get to the project, the more we realize that Thuillier [a scientist who conducted a critical analysis of the project] came out and pointed to everything in the report that was problematic. That's why they [the Technical Support Organization *Institut de Radioprotection et de sûreté nucléaire* – IRSN] said: yes, you're right, graphite waste will not fit in [the deep geological disposal facility] because it's too much trouble. […] What is serious is that we have the impression that the questions are multiplying and […] in the public debate, we still do not know what to put into [the deep geological disposal repository] (French Local Information Committee in a 2014 interview translated from French by the author).

The choice to dispose of the French MOX in a deep geological repository has both technical and economic consequences. The final characteristics of the waste (among other things, its temperature and its radiotoxicity are higher)[18,29] has major consequences for the design of the repository, and as a local political representative (2014) explained, the choice may also affect "the credibility of the waste management implementation strategy." In this sense, these choices, he continued, are "not just a technical issue, even if at first, that is what it may seem."

In Belgium, the blurred categories compelled the Belgian RWM organization ONDRAF/NIRAS to work on two different scenarios concerning deep geological disposal. Either the nonreprocessed spent fuel is considered as waste or as a recoverable material. In the latter case, only the vitrified waste is to be taken into consideration for deep geological disposal (source: interview with a geophysicist employed by ONDRAF/NIRAS in 2013). According to this representative, splitting the scenario in two involves a triple challenge: scientific, economic, and societal. In terms of research and development, specific research programs are needed for each scenario. This duplication also has repercussions for the project costs and waste volumes to be considered: "In our inventory report, there is an obligation to evaluate the cost of the waste but when there are two options like that, there is uncertainty about the cost." Last, the dual choice complicates the management of the societal dimension of the project:

> […] if we [ONDRAF] plan a particular solution for the future, go and see the populations that might be interested in continuing the development of a geological repository [and if we] tell them: "you know, we don't yet really know if we are going to put in: vitrified waste or spent fuel. In one case, it is a few hundred cubic meters, in the other, it is a few thousand cubic meters but we don't know and it does not depend on us." It is an extremely delicate situation (geophysicist employed by ONDRAF/NIRAS in a 2013 interview translated from French by the author).

How can the limits of a top-down radioactive waste classification system be overcome? Some French engineers, including Dessus et al. and Thuillier, advocate for a reclassification of the nuclear waste category to ensure that technical management solutions suit the characteristics of the material to be managed. Section VI suggests one possibility.

## VI. DISCUSSION

The first empirical section of this paper highlighted how naming is a powerful action that has concrete consequences. More than ordering the objects, categorization influences the type of management of the object. Indeed, in the three countries I compared, HLW categories tend to be systematically associated with a long-term deep geological disposal option. In this sense, the current IAEA classification system for radioactive waste and the Canadian, French, and Belgian national classification systems impose a particular way of dealing with the HLW category. Once technically and legally stabilized, once apparently fixed once and for all, the deep geological disposal option seems to be the main if not the only solution for the HLW category. What Lowenthal underlined in the case of the United States could be extrapolated to the Belgian, the Canadian, and the French cases: Historically, all radioactive waste classes have been "top-down classes" as "the waste class is based solely on the characteristics of the waste, not on the disposal environment."[4] The physical properties of the waste do inform the classification approach which then informs the disposal option.

Classification and management were originally envisioned as a sequential process: classifying first and managing afterward. This arrangement allowed RWM organizations to systematically associate the HLW category with deep geological disposal, the reference long-term option, and to design it accordingly. The Canadian case illustrates a priori this sequential process. In the absence of blurred categories, there are no uncertainties related to the type of category that will be disposed of in the future repository and one exclusively focuses on how to manage it.

However, the second part of this paper stressed how some boundary objects (e.g., spent nuclear fuel from MOX fuel in France, and spent nuclear fuel and spent nuclear fuel from MOX fuel in Belgium) blur the current top-down radioactive waste classification systems, partially revealing their limits. Such limits challenge the design of long-term management options and vice versa: Long-term management scenarios are multiplying as the deep geological disposal option is and will be designed according to the volumes and the types of wastes the country has to manage. In Belgium, the nuclear industry owns the spent fuel, stores it at NPP sites, and can influence its status by classifying it as a waste or as a resource. In the long-term, blurred categories constrain the Belgian RWM organization to envisage multiple scenarios. In France, the deep geological disposal repository has a flexible zone (i.e., an area in the repository designed to ensure the adaptability of the Cigeo's facilities[30]) to face waste class uncertainties and the uncertain future of radioactive objects. There is also specific waste (e.g., used MOX) that can create new challenges for the design of the future final repository. These elements confirm Lowenthal's assumptions that there is "a strong linkage between actual disposal facilities and officially established waste classes."[4]

Combined with the limits of the top-down radioactive waste classification system, it demonstrates how classification and management can no longer be considered as a sequential process but rather as a coproduced process in which the act of classifying and the act of managing constantly influence each other.

Considering waste classification systems and (future) disposal site(s) as mutually constitutive adds two concrete elements to assess radioactive waste classification systems. First, I maintain that even the most stabilized one should systematically include a "bottom-up" element (in the sense of Lowenthal) as "waste class is [also] based on the characteristics of the particular disposal site and facility and on the behavior of waste disposed here."[4] In the same vein as the author, I assert that part of the definition of HLW could be that its management option is a deep geological disposal: "a disposal site's waste acceptance criteria are the final words on disposition of wastes at that site and are therefore effectively the final words on waste classification at that location."[4]

Second, one way to overcome the blurred categories could be to reverse the mechanics of the reflection to allow the redefinition of the categorization. This would imply recognizing that it is not a predefined category that induces the choice of a long-term management solution, but the choice of the long-term management solution that defines the contours of a category:

> (…) what is the current definition of low-level waste [LLW]? It is not the waste from such and such activity, the definition [of LLW] is, it is the waste that can go to the [French] Morvilliers Center. We reverse the mechanics. Ultimately, what is high-level waste? Those wastes that can go to the disposal facility. You reverse the mechanics by matching the categorization with disposal facility (French Regulatory Body in a 2014 interview translated from French by the author).

Since the classification and management are interrelated and not part of a sequential process, I would argue that the final repository can be valuable in overcoming the limitations of classification. Indeed, one possibility is to focus primarily on the long-term management option design. Therefore, the key question that arises first is what can actually be included and accepted in the long-term repository? The hypothesis is that the HLW is the one that will ultimately be included in the repository. Taking this idea seriously means that the operationalization of the preferred scenario could redefine the contours of the categories of waste to be included or excluded from the repository.

I stress that assuming the classification and management processes as coproduced is interesting for the future of RWM in three respects. First, the bottom-up waste acceptance criteria of the final repository could clash with top-down definitions of radioactive waste because the three countries studied here have limited options for long-term disposal. Site-specific analysis, the type of host rock, and the type and number of technical and engineering barriers coupled with particular waste add further constraints on HLW management. Second, it seems to shift the focus of attention away from the construction of categories to the construction of the deep geological disposal repository and the emergence of one or more associated categories: Only the authorization to build the geological repository would make it possible to remove the ambiguities concerning the categories of waste that can be disposed of in the facility. Last, while designers of long-term repositories [and more broadly nongovernmental organizations (NGOs) and civil society] have little chance to be heard about a top-down nuclear classification system, they have (unequal) power to influence the design of the management solution. Therefore, designing the deep geological repository would allow nuclear experts, engineer designers, NGOs, and civil society to collectively gain greater control over the definition of HLW, or at the very least, on what is or is not allowed in a future repository.

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## ORCID

Céline Parotte http://orcid.org/0000-0002-8205-4760

## References

1. M. DOUGLAS, *Comment pensent les institutions? Suivi de la connaissance de soi et de Il n'y a pas de don gratuit*, Poche (2004).
2. S. JASANOFF, *States of Knowledge: The Co-production of Science and the Social Order*, Routledge (2004).
3. G. C. BOWKER and S. L. STAR, *Sorting Things Out: Classification and Its Consequences*, MIT Press (2000).
4. M. D. LOWENTHAL, "Radioactive-Waste Classification in the United States: History and Current Predicaments," UCRL-CR–128127, 16339, Lawrence Livermore National Laboratory (1997); https://doi.org/10.2172/16339.
5. *Principes fondamentaux de sureté. Fondements de sureté*, International Atomic Energy Agency, Vienne (2007).
6. C. PAROTTE, *L'Art de gouverner les déchets hautement radioactifs*, Presses Universitaires de Liège, Liège, Belgium (2018).
7. C. PAROTTE, "A Nuclear Real-World Experiment: Exploring the Experimental Mindsets of Radioactive Waste Management Organisations in France, Belgium and Canada," *Energy Res. Soc. Sci.*, **69**, 101761 (2020); https://doi.org/10.1016/j.erss.2020.101761.
8. *Reframing Rights. Bioconstitutionalism in the Genetic Age*, S. JASANOFF, Ed., MIT Press (2011).
9. R. K. YIN, *Case Study Research: V*, SAGE Publications (2013).
10. V. BRAUN and V. CLARKE, "Using Thematic Analysis in Psychology," *Qual. Res. Psychol.*, **3**, *2*, 77 (2006); https://doi.org/10.1191/1478088706qp063oa.
11. P. LASCOUMES, "La Gouvernementalité: De la critique de l'Etat aux technologies du pouvoir," *Portique*, **13–14**, 1 (2004).
12. T. M. PORTER, *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*, Princeton University Press, Princeton, New Jersey (1995).
13. *Classification of Radioactive Waste. A Safety Guide*, p. 52, International Atomic Energy Agency, Vienna (1994).
14. S. L. STAR, "Ceci n'est pas un objet-frontière!," *Rev. Anthropol. Connaiss.*, **4**, 18 (2010).
15. "Uranium and Nuclear Power Facts," Canada and Natural Resources Canada (Aug. 9, 2019); www.nrcan.gc.ca (current as of Nov. 7, 2019).
16. J. M. MILLER and P. C. F. WONG, "19—Canada: Experience of Radioactive Waste (RAW) Management and Contaminated Site Cleanup," *Radioactive Waste Management and Contaminated Site Clean-Up*, pp. 612–635, W. E. LEE, M. I. OJOVAN, and C. M. JANTZEN, Eds., Woodhead Publishing (2013).
17. "Evaluation of the Nuclear Legacy Liabilities Program (NLLP)," Canada and Natural Resources Canada (2018); https://www.nrcan.gc.ca/maps-tools-publications/publications/minerals-mining-publications/evaluation-nuclear-legacy-liabilities-program-nllp/20540 (current as of Nov. 7, 2019).
18. B. DESSUS, Déchets nucléaires stockés à Bure? Une faille majeure dans le projet, le 24 octobre 2013, *Reporterre*, France (2014).
19. *Classification of Radioactive Waste*, p. 78, International Atomic Energy Agency, Vienna (2009).
20. M. MARTELL and G. FERRARO, *Radioactive Waste Management Stakeholders Map in the European Union*, p. 82, European Commission Joint Research Centre Institute for Energy and Transport, Luxembourg (2014).
21. "Standardization of Radioactive Waste Categories," Technical Reports Series 101, p. 24, International Atomic Energy Agency, Vienna (1970).
22. *Policies and Strategies for Radioactive Waste Management*, p. 81, International Atomic Energy Agency, Vienne (2009).
23. C. PAROTTE and P. DELVENNE, "Taming Uncertainty: Towards a New Governance Approach for Nuclear Waste

Management in Belgium," *Technol. Anal. Strateg. Manag.*, **27**, 986 (2015); https://doi.org/10.1080/09537325.2015.1044429.

24. "National Programme for the Management of Spent Fuel and Radioactive Waste. Document Drafted by the National Programme Committee Pursuant to the Law of 3 June 2014 Transposing European Directive 2011/70/Euratom of 19 July 2011," Courtesy translation, Alberto Fernandez Fernandez, FPS Economy, S.M.E.s, Self-Employed and Energy, p. 78, Directorate General for Energy, Nuclear Energy Division, Belgium (2015).
25. *Nuclear Fuel Waste Act*, "Consolidated Acts, in S.C. 2002," p. c.23, Canada (2002).
26. J. VAN VLIET, A. MICHEL, and L. BINDLER, "Belgonucléaire 1990–2005," *Histoire du nucléaire en Belgique 1990–2005*, P. LANG, Ed., pp. 185–200, Peter Lang, Bruxelles (2007).
27. S. BENSON et al., *Reset of America's Nuclear Waste Management. Strategy and Policy 2018*, p. 126, Stanford University, George Washington University (2018).
28. "Bilan du débat public. Projet de centre de stockage réversible profond de déchets radioactifs en Meuse/Haute Marne (Cigéo) 15 mai- décembre 2013," p. 20, CNDP (2014).
29. B. D. SOLOMON, M. ANDRÈN, and U. STRANDBERG, "Three Decades of Social Science Research on High-Level Nuclear Waste: Achievements and Future Challenges," *Risk Hazards Crisis Public Policy*, **1**, *4*, 12 (2010); https://doi.org/10.2202/1944-4079.1036.
30. P. C. LEVERD et al., "Cigeo—Proposed Operations Master Plan (PDE)," CG-TE-D-NTE-AMOA-SDR-0000-15-0063/A, p. 99, ANDRA (2016).