

The Efficacy Paradox Revisited: “Closing Up” Commitments in Nuclear Waste Governance

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Abstract

It is well established in science and technology studies that participation and expert analysis should not be seen as contradictory. Key analytical questions include how both public and expert knowledge contribute to “closing down” and “opening up” appraisals and commitments, and how important these dynamics are in assessing the process and the conditions of democratizing technology. This article examines how the participatory turn has affected nuclear waste governance options in France and Canada. Through cross-case analysis, it describes how at each constitutive step of management programs, public and expert knowledge has followed a variety of pathways in (in)forming commitments, resulting in asymmetrical trade-offs. The term “closing up commitment” is introduced to refer to the way both national governments finally opted for closing the technological options at

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hand while introducing new conditions that might challenge future actions. We argue that paying attention to this mutation in nuclear governance allows for a more detailed analysis of power distributions in science and technology governance than a critical approach that rejects any closure because it can be (and often is) the result of an instrumental approach undertaken by the incumbent actors.

Keywords

radioactive waste management, participatory deliberation, expert analysis, closing up, power asymmetries, mutation

Introduction

To foster public engagement in the governance of science and technology, a so-called participatory turn in environmental issues was undertaken from the 1990s (Pestre 2014). Nuclear waste management is one of the sectors where this turn was institutionalized by moving from a predominantly expert-based approach to participatory practices involving experts, citizens, and stakeholders (Bergmans et al. 2014; Sundqvist and Elam 2010; Johnson 2007). European and national nuclear waste management projects were funded to allow for a variety of new processes and deliberative procedures (Brunnengraber and Di Nucci 2019; Brunnengraber et al. 2015) and to address a wide array of governance issues such as: how can nuclear societies design sociotechnical solutions to deal with an object that is toxic for humans and the environment with a half-life that seems endless? What are the relevant dimensions that constitute the best option to deal with nuclear waste, according to whom? Who can participate in the production of knowledge about nuclear issues? Who has the authority to assess the production of knowledge and to take a management decision? How to decide? When is it time to do so?

In science and technology studies (STS), Andrew Stirling's 2008 article "'Opening Up' and 'Closing Down'" has been widely cited and is influential particularly because it conceptualized an approach that transcended the dichotomy between expert analysis and public participation. Stirling (2008) famously argued that it was urgent to focus on how "both were susceptible to instrumental framing for variously weak and strong forms of justification" (p. 262). His starting point was anchored in a puzzling

observation: even though languages of participation proliferate in policy debates, the impact of participatory exercises is rather limited and does not seem to modify the linear and deterministic conception of technological progress. As a result, “incumbent interests typically act instrumentally to frame [participatory– or expert-based] appraisal such as to ‘close down’ the range of possible technological commitments” (Stirling 2008, 264). Stirling and colleagues define appraisal as “an array of social processes through which knowledges are produced and gathered in order to inform decision-making and associated institutional commitments” (Ely, Van Zwanenberg, and Stirling 2014, 507). “Commitment” is about formulating concrete decisions for certain technological pathways and encompasses a range of structures and processes for allocating resources, shaping political priorities, or building infrastructures (Stirling 2008, 265).

The governance processes we analyze in this article illustrate how the participatory turn has affected nuclear waste management options in France and Canada and lead us to nuance Stirling’s assertion that closure would necessarily be favorable to incumbent interests. At the very least, we see that this is not the whole story and that there is still much to discover, both empirically and theoretically. Following extensive consultations with experts and publics, geological disposal—the solution preferred by international waste management agency experts for decades—has indeed emerged as the reference option in both countries. Yet, by dissecting the conditions of approval of this option, we find that this cannot be reduced to the mere success of an instrumental approach undertaken by the incumbent actors to manipulate the lay participants and achieve objectives already set without them, as critical authors might, a little too hastily, conclude. Indeed, the outcomes were shaped by deliberated social values, such as the reversibility or retrievability of waste, and it is important to look at what this means in concrete terms when thinking about future relations between experts and the publics concerned. As Stirling (2008) anticipated, “when a relatively broad appraisal process is subject to closing down, [...] then tensions may be expected about the specificity and contestability of the particular axis of closure” (p. 283). Rather than immediate tensions, the situations we analyzed highlighted trade-offs between public and expert knowledge that were deemed necessary for the continuation of nuclear waste management programs. We argue that these asymmetrical trade-offs allow us to deepen and revisit the paradox of efficacy (Voß, Kemp, and Bauknecht 2006), which holds that technological solutions must be

subject to dialogue and the openness of possibilities to be socially robust, while at some point or in some situations, it is desirable to reduce complexity to a single coherent course of action to avoid paralyzing governance actions.

To conduct the longitudinal analysis of our case studies, we ask two guiding research questions: (1) has the integration of public and expert knowledge in nuclear waste management programs led to the opening up or closing down of technological appraisals? and (2) what institutional commitments have emerged from these processes?

The paper is divided into four sections. The second section summarizes key components of the theoretical framework developed by Andy Stirling and his colleagues that we adopt. Following calls for empirical testing of the opening up/closing down theoretical framework published by Ely, Van Zwanenberg, and Stirling (2014), in the third section, we present two detailed and empirically grounded case studies of nuclear waste management, one in France and the other in Canada. This section completes a series of earlier attempts at empirical testing of Stirling's work directly applied to nuclear issues: nuclear waste management processes in Belgium with Parotte and Delvenne (2015); UK nuclear institutions with Chilvers and Burgess (2008); and deliberative nuclear decision-making in the UK, Finland, and France with Lehtonen (2010). Unlike most papers, which have mainly focused on appraisals when using this framework, we directly address the commitments themselves. In 2008, Stirling already considered this as an important step forward because "greater appreciation is required—in both analytic and participatory appraisal—to facilitating the opening up (rather than the closing down) of governance commitments on science and technology" (Stirling 2008, 262). In the Discussion section (the fourth section), our findings test this normative inclination by showing that, in practice, technological commitments do emerge in between opening up and closing down: what we term "closing up" commitments in this paper. Such closing up commitments recognize the need to find compromise solutions capable of easing tensions while breaking the governance impasse and providing guidance in decision-making despite the incalculability of several dimensions whose uncertainty is acknowledged but displaced into the future. We conclude that these results invite re-examination and enrichment of the meaning and the use of existing conceptual frameworks to analyze sociotechnical appraisals and commitments.

A Theoretical Framework for a Longitudinal Analysis of Technological Processes

Opening Up and Closing Down Technological Appraisals and Commitments

Stirling and colleagues begin by distinguishing two processes in technology governance understood as encompassing the diverse totality of actors, discourses, structures, and processes implicated in guiding and shaping technological configuration (Stirling 2008, 265). These processes, namely appraisal and commitment, are parallel, interlinked, and mutually co-constituting (Smith and Stirling 2007; Ely, Van Zwanenberg, and Stirling 2014; Smith, Stirling, and Berkhout 2005; Stirling 2006). In short, appraising is about ways of knowing and informing while committing is about making decisions, shaping technological priorities, and allocating institutional and economic resources.

As a second step, Stirling and colleagues question participation as a one-size-fits-all solution to properly inform technology governance. Indeed, at least at the time the article was published, there was an increasing tendency to glorify participation when appraising science and technology and to create a false dichotomy with expert analysis (Stirling 2008). This is, as we stressed above, visible for instance, in the participatory turn of most nuclear waste management agencies. Indeed, not limited to nuclear governance, decision makers and scholars alike encourage different types of engagement, ranging from participatory methods involving stakeholders and the public to upstream and downstream processes of knowledge production and participatory innovation management (Wilsdon and Willis 2004). Rather than normatively arguing for the engagement of stakeholders and the public, Stirling's work transcends the contrast between participation and expert inputs that, in his opinion, creates an unnecessary dichotomy.

Expert analysis and public participation actually have a lot in common: both are subject to framing conditions (Blok 2007; Jensen 2005), pervaded by power relations, vulnerable to strategic behaviors, consensus-oriented, and likely to serve similar justificatory purposes (Chilvers and Burgess 2008; Stirling 2006; Fiorino 1990). For Stirling (2006, 2008) and Smith and Stirling (2007), these similarities between expert analysis and public participation are reflected analytically in the dynamics that lead to opening up or closing down the governance of technology. Closing down is about defining the right questions, finding the priority issues, identifying salient knowledge, and recruiting appropriate protagonists to determine the "best"

options. Opening up, by contrast, entails a greater degree of reflexivity. It reveals the open-endedness, contingencies, and capacities for social agency in technology choice. Instead of focusing only on prescriptive recommendations, open appraisal poses alternative questions, focuses on neglected issues, includes marginalized perspectives, triangulates contending knowledge, tests sensitivities to different methods, considers ignored uncertainties, examines different possibilities, and highlights new options (Stirling 2008, 278-80).

The Efficacy Paradox of Handling Complexity

The strategies used by governance agents cannot only be based on further opening up (Voß, Kemp, and Bauknecht 2006, 431). At some point, closing down is also necessary while being fully aware of the reduction of complexity involved (Kemp, Parto, and Gibson 2005, 438). In this respect, it is important to keep in mind that a necessary balance between opening up and closing down moments has to be found for institutional and political commitments to be made and decisions to be taken. The key analytical question then concerns the moments and situations in which opening up would be desirable, and when, by contrast, it would be better to close down. This is in order to handle the “efficacy paradox of handling complexity,” which is defined as:

the contradicting requirements of opening up and closing down in social problem-solving processes. On the one hand, problem-oriented interactions need to be opened to take account of the interaction of diverse factors, values and interests. This is necessary to produce robust knowledge and strategies. On the other hand, selection of relevant factors, decisions about ambiguous evaluations and convergence of interests are necessary to take decisions and act. (Voß, Kemp, and Bauknecht 2006, 420)

This paradox draws on the fact that “too much complexity, ambivalence and interaction severely reduce action capacities and may block deliberate attempts at shaping societal development” (Voß, Kemp, and Bauknecht 2006, 429). The authors claim that the paradox cannot be resolved without losing on the side of social robustness or on the side of effectiveness of decisions and actions. Therefore, “it’s useful to recognize the paradox, not to resolve it, but to work with it” (Voß, Kemp, and Bauknecht 2006, 431). To do so, these authors suggested a typology of generic combinations of opening up and closing down governance processes. To cover the full

spectrum of possibilities from the most open to the most closed, they include “erosion of strategic possibilities” (totally open), “exploring experiments” (in which the opening phase is extended by a variety of problem-handling frameworks developed in a portfolio of strategic activities that take place in parallel, which consequently increases complexity), “sequential opening and closing” (in which the opening phase is pragmatically reduced to a single coherent course of action), and finally “problem solving with blinkers” (totally closed; Voß, Kemp, and Bauknecht 2006, 433-35).

In the next section, we present and analyze our case studies in the light of this conceptual framework. Even though France and Canada present contextual specificities, reflect different political cultures, or have distinct geological and territorial characteristics, the two national trajectories of the nuclear waste management programs and the alternating phases of opening up and closing down we studied are remarkably similar. Drawing on the generic combinations suggested by Voß, Kemp, and Bauknecht (2006), both trajectories reflect sequential opening and closing in the nuclear waste governance processes after a parenthesis of a few years during which the option of exploring experiments was implemented.

Cross-case Analysis: The Participatory Turn and the Opening Up of Nuclear Waste Management Programs in France and Canada

Data Collection and Analysis

To understand the total diversity of actors, discourses, structures, and processes involved in guiding and shaping technological configuration (Stirling 2008, 265), our analysis relies on data collected by one of the author between 2014 and 2018 (Parotte 2018). We combine different qualitative methods to ensure in-depth analysis: document analysis, semi-structured interviews, and participatory observations. The secondary data include media articles, legislation, official reports, and the official websites of nuclear waste management agencies. To gather the primary data, participatory observations were conducted to report on local support or contestation at sites targeted by geological repository projects, to document the visible signs of nuclear waste management agencies at these sites, to analyze the concrete organization of local information campaigns, and finally to know the spatial organization of the sites. We visited expected future

sites for radioactive waste repositories in Bure, France, in 2014 and 2018; we also visited four Canadian municipalities that had volunteered to be part of the siting process (Manitouwadge, Nipigon, Schreiber, and Ignace), and to potentially host a high-level radioactive waste (HLRW) repository. In France, thirty-two interviews were conducted in 2014 and 2018; in Canada, seventeen interviews were conducted in 2015. In France, most interviews were with representatives of the local committee for information and monitoring of the nuclear waste management project (thirteen), but also national-level representatives of consultative bodies (seven), safety authorities (four), HLRW experts (three), journalists (two), and employees of the French National Agency for Radioactive Waste Management (ANDRA; three). In Canada, the interviewees included representatives of the four official Community Liaison Committees between the Nuclear Waste Management Organization (NWMO) and the four municipalities mentioned above (eight), safety authority (one), federal consultative bodies (two), policy makers (two), NWMO (two), and HLRW scientists (two).

For each case study, a full chronological description of each case was built using opening up/closing down framework described by Stirling (2008). Favoring longitudinal analysis allowed us to highlight the sequential process of appraisals and commitments to identify the actors who intervene (when, how often, and on what topic). With document analysis, we first identified the succession of formal appraisals (based on expertise and participation), the commitments that have been made over time, and analyzed how they relate to each other. We compiled an exhaustive list to construct a time line that gave us an overview of the trajectory of nuclear waste governance in Canada and France. In the second step, we asked our interviewees which appraisals and commitments they considered to be the most important and the most influential in the nuclear waste program and why. These interviews were instrumental in understanding the issues, practices, and discourses that allowed the construction of different appraisals and commitments. In order to go beyond interpretations given by the actors and empirically ground our theoretical contribution, we chose to refer to the materiality that serves as proof, remains over time, and is ultimately imposed on all actors involved: the written legal documents and official reports that embody the commitments. This explains why we mainly quote legal documents in the empirical section to describe the “closing up commitments” made in the two case studies.

Mounting Social Protest Triggered the Participatory Turn as New Actors Entered the Stage

From the 1950s to the 1980s, dealing with nuclear waste was first and foremost a prerogative of the state and of scientific experts. In the two countries we studied, nuclear research centers,¹ nuclear industries, and members of the government² were the only people responsible for finding a solution to the nuclear waste produced in their territory.

It was also at that time that geological disposal gradually began to be presented as the only technical option for managing HLRW. In Canada, several expert reports—including the so-called Hare report (Aiken, Harrison, and Hare 1977) and two AECL reports (AECL 1978, 1994)—supported this option and recommended applying it as soon as possible in two different Ontarian sites “because Ontario would be the principal waste-producing province” (CEAA 1998, 7). In France, geological disposal was also preferred from the late 1970s—a position that was further reinforced by the birth of ANDRA, a state expert agency specifically in charge of studying the feasibility of geological disposal (Barthe 2006, 57). In 1987, based on technical criteria approved by the French Minister of Industry, the agency identified four potential sites that were geologically favorable to receiving this kind of waste (OPECST 1990, 54).

In both countries, local populations strongly contested the siting processes of the technical option suggested in nuclear waste programs (Barthe 2006; Durant 2009; Durant and Stanley 2009), which forced governments to change the way they normally dealt with such issues. It is in this context of crisis that new actors entered the stage and were appointed by the executives as independent assessors of the nuclear programs: the Parliamentary office of Technology Assessment in France (Office Parlementaire d’Evaluation des Choix Scientifiques et Technologiques [OPECST]) and an Independent Expert Panel in Canada. In France, Prime Minister Michel Rocard announced a one-year moratorium on nuclear waste research in 1990 and argued for a “more open process” with a “style of government that promote[s] dialogue and compromise” (Barthe 2009, 949). To this end, the newly formed Parliamentary office of Technology Assessment was tasked with assessing the nuclear program (Parotte and Delvenne 2018). In 1981, in Canada, the Federal and Ontario Governments jointly stated that “both site selection and implementation authority would not proceed or be decided on until after the disposal concept itself had been accepted” (EMR and Ontario Energy Minister 1981 cited in Durant and Stanley 2009, 34). In 1989, an Independent Environmental Assessment Panel also called the

Seaborn Panel, named after its former president, was appointed to assess the research program proposed by AECL (CEAA 1998).

Those two governmental commitments made in 1981 in Canada and in 1990 in France were key moments in their respective nuclear waste management programs because they triggered the participatory turn we discuss in the following section.

The Opening up of Technological Appraisals

The participatory turn in France and Canada led to a substantial broadening of inputs into sociotechnical appraisals of nuclear waste management.

In Canada, the Seaborn Panel organized an unprecedented ten-year assessment (1989-1998) by initiating several national and local public and expert consultations. Beyond its length, this assessment was exceptional because of the multiplicity of consultative events, the diversity of publics invited to take part, and the systematized and iterative method of consultation. Federal, provincial, local-elected representatives, universities, community organizations, First Nation Communities, government agencies, technical specialists, and an independent scientific review group were asked to assess ethical and social issues (Timmerman 2009, 54) as well as the technical and safety dimensions of the existing nuclear waste disposal program (CEAA 1998, 8).

The Canadian panel first recognized the sociotechnical nature of the process, concluding that “safety [was] a key part of the solution, but only one part of social acceptability. Safety must be viewed from two complementary perspectives: technical and social” (CEAA 1998, 4). Yet the Seaborn panel’s reasoning immediately returned to a separation of the social order from the technical order, adding that “from a technical perspective, the safety of the [Nuclear Research Center] concept has been adequately demonstrated for conceptual development, but from a social perspective, it has not” (CEAA 1998, 4).

In France, OPECST organized several consultations with national and local publics and experts in Parliament over the course of a year 1990. The advantages and disadvantages of the geological disposal option were discussed through inclusive procedures (Barthe 2002). For instance, the waste producers and the local council were invited to present their own perspectives and interests, alongside local policy makers and environmentalist groups. During this appraisal, OPECST reconsidered the technical options previously excluded from the nuclear waste decision-making process in order to comprehensively assess all possible options, including those that

seemed less viable. The Office noted that almost all the experts interviewed supported the geological disposal option over the “unrealistic” and “unfeasible” options such as sending waste into space, exporting them to third world countries and burying them in marine sediments (OPECST 1990, 30-34). Meanwhile, local people and officials criticized the lack of national and local information and of a debate on the nuclear waste program per se.

OPECST’s appraisal therefore suggested exploring two new research options, permanent near-surface storage and partitioning and transmutation of long-living radioactive elements. OPECST stressed the importance of exploring several options for research laboratories and of separating the repository siting process from that of the underground laboratories. It also supported the idea of organizing systematic consultations of the local populations concerned, local political representatives and national experts, and recommended institutionalizing both a local information committee and a national expert committee (OPECST 1990, 92-94).

The Formation of Open Commitments for Nuclear Waste Programs

The appraisal series in France and Canada led to an opening up of commitments for nuclear waste management programs in the two countries. In France, the national Parliament adopted the Waste Act of 1991, also called the Bataille Law after the name of the influential OPECST member who served as the official rapporteur of the parliamentary committee. The nuclear waste program was indeed opened up, as the 1991 law provided for the study of three options: deep geological disposal, permanent surface storage, and partitioning and transmutation. Rather than discussing the location of a final repository, the next step of the nuclear waste program was to identify the most appropriate host rock for the disposal of nuclear waste. The Waste Act stipulated the independence of a public NWMO and provided for the establishment of a new committee of independent experts to monitor the research. Through this legislative act, Members of Parliament also stated that several different actors should evaluate the nuclear waste program and that Parliament should be the primary institution responsible for defining the program. The Bataille Law further stipulated that at the local level, elected representatives should also be more deeply involved, and that by 2005, the Parliament should commit to one of the three options for the national nuclear waste management program.

In Canada, the Federal Parliament adopted the Nuclear Fuel Act in 2002. Slightly differing from the options chosen in France, the Canadian

commitment also stressed that three options had to be explored in parallel and compared: deep geological disposal in the Canadian Shield, storage at nuclear reactor sites, and centralized storage (either above or below ground). In addition, the Nuclear Fuel Act specified that local populations and experts should be consulted on these technical options and mandated the creation of a new nonprofit organization called the NWMO, established and funded by nuclear energy corporations, to handle the future consultations. Like the French, the Canadian Parliament proposed 2005 as the deadline for evaluating the program and choosing a long-term option.

To summarize, the participatory turn led to a significant moment of opening up of prevailing governance practices in both France and Canada, which meant including publics previously excluded from the nuclear waste program in technological appraisals. This period was significant for at least three reasons. First, the nuclear waste program was recognized as a socio-technical issue by the state and by the scientific community. Second, it opened up long-term nuclear waste management to new research options beyond geological disposal. Third, it led to new, more inclusive procedures that improve information and dialogue, provide new ethical principles, and involve the exploration of new research options.

Toward New Technological Commitments

The new Canadian NWMO organized an intense four-year process of iterative, broad-based consultations with experts and the public before concluding that each of the three options had their own strengths and their own limitations—and that none fully met their expectations. For instance, the deep geological disposal in the Canadian shield offered “multiple barriers and passive” containment that isolates the used fuel from people in “a permanent or definitive way,” but with less institutional control and difficulties to monitor and retrieve the waste. The storage on nuclear sites involved “minimal transportation and it allows the used fuel to be easily accessed and monitored,” but the management approach on multiple storage sites could increase costs and “uneven applications of procedures” at different sites. The centralized storage above or below ground “could be established in many different settings” and was considered “flexible and retrievable” but required “maintaining the commitment to manage and care for the used fuel” for subsequent generations (NWMO 2005a, 85-91).

This is why the NWMO suggested developing a fourth option never previously considered, “which combines the strengths of each of the three options” (NWMO 2005a, 95): the Adaptive Phase Management (APM).

This fourth option offered the benefits of implementing an approach, which in the long term does not require institutional control to be effective (the geological disposal), while providing a period of easy access and active monitoring capability up to that point. Furthermore, the phased option was seen as positive because it “allows for both current and near-term generations to participate in the selection and design of a long-term approach before it is fully implemented” (NWMO 2005a, 217), while offering “flexibility in the pace and manner of implementation through phased decision-making” (NWMO 2005b, 17).

In 2007, the Canadian Federal Government validated this APM approach, which supported deep geological disposal combined with monitoring and retrievability and “sequential and reversible” decision-making process.

In France, for about fifteen years, several national evaluation and consultation bodies have been responsible for evaluating one or more dimensions of the high-level waste process (Lehtonen 2015). The limits and added value of the three research options studied (deep geological disposal, permanent surface storage, and partitioning and transmutation) were debated according different criteria. For instance, in 1995, the National Assessment Board (French acronym CEN) considered the scientific maturity of the option as a key element and stressed that the “[nuclear research program should] find a compromise between the desirable objectives and the real possibilities of application” (CEN 1995, 10). A little less than a decade later, in 2006, CEN supported geological disposal, considering that the “eternal [surface] storage [had to] be excluded [...] and that] partitioning/transmutation aims at reducing the amount of waste [that] should move into geological disposal” (CEN 2006, 6).

In 1996 and 1998, OPECST argued that its scientific evaluation showed how difficult it would be to implement the partitioning/transmutation option—for both financial and technical reasons. The Office also suggested studying reversibility as an additional condition for adopting geological disposal because it could be “a key element of the trust of the population affected by the construction of the underground repository. It will keep some options open for future generations” (OPECST 1996, 107). Second, it argued that long-term storage should be further studied in order to challenge the option of geological disposal.

In 2005, the National Commission of Public Debate (French acronym CNDP) concluded that having a choice between several technical options was important and that “two technical solutions should be offered to citizens... rather than one that could be imposed *de facto*” (Mercadal et al.

2006, 104). The same year, OPECST stressed that there was a need to “move forward in the path opened by the Waste Act in 1991 [and] take our responsibilities for the future generations” (OPECST 2005, 10). The Office stressed that surface storage was temporarily necessary only for short-term management and was therefore not relevant as a long-term nuclear waste management approach. The partitioning/transmutation option was a promising R&D avenue for future waste, but as it was still awaiting industrialization, it was not considered realistic sooner than two or three decades into the future. It was thus considered as a possible future solution to be applied to future waste. OPECST concluded that the most relevant long-term solution was geological disposal, combined with an additional condition. Drawing on the results of consultations with the affected publics held in recent years, OPECST suggested adding reversibility to geological disposal in order “to select the safest technical option and at the same time keep choices open” (OPECST 2005, 64).

In France, geological disposal was validated in a new commitment, the Planning Act of 2006, which also provided for reversibility in nuclear waste management.

The French and Canadian commitments of 2006 and 2007 are neither a commitment to complete closure nor a commitment to complete opening. A complete closing down commitment would have meant a return to the nuclear waste program of the 1970s and the continuation of geological disposal with no further conditions. A complete opening up commitment would have meant maintaining ongoing research programs on several disposal technology options. More than simply replicating purely “opening up” and “closing down” dynamics, both commitments display a curious form of hybridization. In the following section, we point out that this form of commitment we call “closing up” was a strategic way to advance nuclear waste management programs and, at the same time, carries the potential to concretely alter the future design of the validated solution.

Discussion: “Closing Up” and the Efficacy Paradox Revisited

A “closing up commitment” combines two factors: narrowing the available options (in this case in favor of the geological disposal option) and introducing new implementation conditions (French reversibility or Canadian adaptive phased management) that carry within them the seeds of a future opening up.

While the two commitments are mainly concerned with outcomes (to secure the option of geological disposal), the perception of the accompanying conditions is quite different in each country and reflects both the advancement and the fragility enabled by these new conditions. On the one hand, in Canada, closing up is linked to a substantive imperative, because the participating publics consider that APM guarantees a procedural quality capable of generating better results based on common values, such as the possibility of including plural perspectives at any time. However, as a result, the closing up commitment has the side effect of numbing institutionalized participation. With routine and massively encouraged participation, geological disposal is now no longer seen as a novel industrial project but as an “ordinary” one. Reassured about the process and the industrial project, voluntarily engaged local communities now almost passively wait for the process to continue and forsake organized consultations (Parotte 2018, 166).³ On the other hand, in France, closing up is linked to an instrumental imperative—that of securing a particular result by attaching conditions whose implementation will be defined from above, and no longer rely on social deliberation from below. Conversely, here the closing up commitment is indirectly responsible for awakening activist and violent participation.

In both cases, the future of nuclear waste management is linked to events whose emergence is based on a widening of the demand for justice and care for the concerns of various affected publics. While the Canadian APM approach seems better suited to procedurally address these concerns when they arise in the future, the French closing up commitment is linked to advancing the long-preferred management option, giving formerly participating publics the impression that they are losing their grip on the future of nuclear waste management. However, in both cases, the conditions of retrievability and reversibility pose social and technical challenges to everything that has been agreed upon, because the creation of the geological repository is suspended and depends on the future capacity to accompany this management option with the guarantees promised and written into the law. These conditions require a set of procedures for collective decision-making, with specific spaces for future generations and new/enlarged (affected) publics to contribute to the programs or to explore sociotechnical alternatives if unexpected events take place.

As a result, what we face is not the traditional efficacy paradox that emphasized balancing between moments of opening and closing in order to allow for the actual governance of the technology (Voß, Kemp, and Bauknecht 2006). The processes that led to Canadian and French nuclear

waste management plans are an altered form of the efficacy paradox because to avoid paralysis and to allow further action to be taken, a compromise closes some of the options while leaving open and uncertain the application of new sociotechnical conditions associated with the chosen option. In other words, there is no need to choose immediately between “keeping up action capacity or opening up problem handling for contextualization” (Voß, Kemp, and Bauknecht 2006), because the commitment allows both, for now.

This revisited efficacy paradox should not be interpreted in a sequential manner, as if closure were only the first step accompanied by a reduction in complexity, and then, in the second step, the opening up of certain dimensions would feed complexity again, but only marginally. It both reduces and increases complexity and uncertainty. The “closing” and the “up” are irretrievably linked in, and through, the commitment: without the first, no second and vice versa. As the outcome of the participatory turn in both countries, the closing up commitment conjugates power relations, to paraphrase Hecht (2002), by simultaneously enacting continuity and change, thus highlighting the dynamic between the two and their inseparability.⁴

Yet we speak of closing up, not “opening down” because the commitment narrows the process around one management option (closing) but also creates openings and possibilities for change within that framework (up), whose effects are still undetermined and could be limited but significant. “Closure” denotes asymmetrical relations between the dynamics of opening and closing. Closing up is the result of uneven power relations in which incumbent actors enforce their own framing, but participating publics sometimes include neglected perspectives or ignored uncertainties. The latter could change the overall nuclear waste management programs, for example, with a possible vote to withdraw the offer from the Canadian community to host nuclear waste facility, or the emergence of new technical challenges to retrieve nuclear waste, or to reverse one or more steps in the planning for a nuclear waste repository in France.

In fact, the effects of the “up” are already visible. For instance, ensuring reversibility and retrievability of waste was debated in the French Parliament in 2016 and, at the time of writing, remains a challenging component of the geological disposal design for many engineers. In 2007, the Nuclear Energy Agency (NEA) launched a four-year project dedicated reversibility and retrievability. The Organisation for Economic Co-operation and Development (OECD) also organized a conference in 2011 dedicated to studying its feasibility in planning geological disposal of radioactive waste (OECD and NEA 2012). In Canada, APM led to the spontaneous withdrawal of one

municipality (Nipigon), and it included additional criteria to select the host site (e.g., strong support by the local population, permanent inclusiveness of affected publics).

Analytically, the notion of closing up illustrates how public and expert knowledge *actually* influence a policy commitment, by revealing a combination of rationales behind the commitment, which *potentially* draws new pathways for the technology program. At the end of the day, we can still ask: do these closing up commitments legitimate already-made technical decisions and thus serve as “technologies of legitimation” (see Stirling 2008; Harrison and Mort 1998), or do they represent the emergence of “technologies of humility” (Jasanoff 2012, 179) that consider unforeseen consequences or that seek to incorporate multiple viewpoints through collective learning?

Paying attention to the contextual hybridization of closing down and opening up provides a richer account of what is at play in France and Canada. The concept of hybridity has received a lot of attention in STS (Prins 1995; Latour 1996; Rabinow 1999) and has been very productive in highlighting how techno-scientific objects are complex fusions of nature and culture. However, here it is more appropriate to consider how Joseph Masco (2004, 2006) used the concept of mutation to extend the theorization of nature–culture forms. Returning to the original definition of the biological hybrid, Masco (2006) reminds us that “the hybrid is in a strict sense a form of generational stasis, allowing one to separate analytically the distinct genetic lines that came together to create the infertile being” (p. 300). In his view, given its focus on parental elements and temporal orientation toward the present, the concept of hybridity limits our ability to recognize and apprehend long-term governance transformations. By contrast, the concept of mutation (a mechanism of biological change whose results are uncertain because they can be beneficial, deleterious or neutral) implies a complex coding of time (past and future) and assumes changes without judging the temporal scale or the type of change that will occur. Hence, our theoretical contribution of closing up commitment could be considered a “mutation” in nuclear governance. Indeed, a closing up commitment is anything but infertile because it “marks a transformation that [will be] reproduced generationally, making the mutation a specific kind of break with the past that reinvents the future” (Masco 2004, 552).

Masco’s work focuses on changes in social and biological ecologies, whereas mutation in nuclear governance describes interventions whose effects are still uncertain, but which cover very long-term possibilities. Recognizing the entanglements and interdependencies afforded by closing

up commitments avoids the trap of merely criticizing the outcomes of participatory processes while expressing a commitment to a broader principle of democratization, as the academic literature on public engagement has tended to do in recent decades (Irwin, Jensen, and Jones 2012). Critical nuclear experts might not agree with us. For example, Topçu (2013), who analyzes the case of France, or Durant and Stanley (2009) or Johnson (2007), who analyze the case of Canada, defend the idea that when nuclear establishment actors create spaces for engagement and participation, it is to better identify and absorb criticism and adapt accordingly. Therefore, in their analysis, decision-making remains in the hands of those who have always had it, and the participatory turn and its devices are instruments for absorbing invited public engagements (Wynne 2007). When Topçu (2013) analyzes the historical trajectory of nuclear power criticism and controversy in France, she considers that “the ‘sovereign’ power (the State and its nuclear promotion and regulation structures) retains its autonomy in making key decisions” and that “the power wrested by criticism [. . .] is thus exercised, more or less, in the service of nuclear power” (Topçu 2013, 93, our translation). Similarly, when Johnson (2007) analyzes the significance of the participatory turn in Canadian nuclear waste management, she considers that “the strength [of the deliberative democratic effort] was attenuated by power dynamics” because “behind closed doors and in closed-loop negotiations with stakeholders, those responsible for formulating the nuclear waste management asserted their dominance” (p. 93). According to these perspectives, the epicenter of power invariably (hopelessly?) remains stable and thus concentrates decision-making capacity within its structures when committing to a specific nuclear waste management option.

Had we used such a critical approach, we could have emphasized the “closing” of appraisal and commitment, concluding that the issues put to the public are limited, that institutional actors resist accounting for the outputs of engagement by insisting on the higher value of solutions put forward by scientific experts, and so on. This would have had both analytical and political value in depicting part of what is happening and providing an important statement on the pitfalls of participation as it is enacted. However, we argue for a finer understanding of what participation can induce and how to describe it analytically.

By working along the lines set down by Stirling and coining the term “closing up,” we provide a richer account of what was at play in France and Canada: neither a full closing down nor a full opening up, but something that—even if highly restricted—creates opportunities for incremental change. In addition to a finer analytical grain, this way of describing

decision-making processes avoids a pattern of case study followed by critical assessment, which may frustrate organizers of participatory exercises, as well as participating citizens, and experts who have been working on particular pathways for decades (see also Irwin, Jensen, and Jones 2012). Recognizing the breaches in which change can unfold is a way of pursuing the process of continuously improving public participation in science and technology—limited as it may be.

Conclusion: Taking Care of the “Up” in a Closed Technological Program

In a context of high uncertainty, the authority of experts is regularly challenged. New knowledge can appear, gain traction, and the question of “preferred forms of expertise” is raised (Jasanoff 2004, 40). In nuclear waste management, it seems that public knowledge has been competing or complementing expert knowledge in a more systematic and institutionalized way since the participatory turn of the 1990s. Everyone wants to shape the decision-making process with new technological options, new questions, new framings, or to fight to maintain the technological program as it was originally defined.

Building on the theoretical work undertaken by Stirling and his colleagues to analyze the governance of science and technology, we argue it is important to understand how public and expert knowledge can actually influence a particular policy agenda (and identify what has been lost in the process), while paying attention to the reasons behind each technology design choice, and what social agency remains after commitments in the form of legislation or policy programs are made.

By studying the trajectories of nuclear waste management in France and Canada, we have highlighted a specific form of commitment that emerges at the uneven intersection of expert analysis and participatory knowledge integration. We term this a closing up commitment that reflects an experimental attempt to maintain the scientific and social order as a whole, to continue nuclear waste management programs, and to partially incorporate the concerns and uncertainties associated with these projects. We have characterized this form of commitment as a mutation, which irrevocably indicates a change in the governance of nuclear technology but whose content, scope, and effects (which may be positive, negative, or nonexistent for the stakeholders involved and for future generations) cannot yet be measured or fully appreciated.

Openings are appearing in what were originally purely technical programs that enable the emergence of new substantive and procedural conditions—such as reversibility in France and adaptive phased management in Canada. Far from being anecdotal, these conditions imperfectly connect the nuclear waste program to audiences and to the production of expert knowledge and act as a permanent lever to keep (new) sociotechnical issues open to broader public debate.

Observing the uneven balance registered by the closing up commitment, some critical researchers and disappointed publics previously involved in such processes express their critique from an outside perspective or even resign themselves to silence. For instance, in France, active opponents to the national nuclear waste program no longer see the reversibility condition as an issue on which they can act. In Canada, the nuclear waste management process has received less academic attention since the adoption of the APM approach. In a way, disinterest seals off openings and thus undermines some of the possibilities for public deliberation of possible choices regarding nuclear waste management. As STS researchers, nuclear practitioners, experts, or concerned publics, we should explore how the “up” survives, and under what conditions it offers additional space for the current nuclear waste debate. It is not only a matter of analyzing how cultural practices of science adjust in response to the contexts in which science is done (Jasanoff 2004, 276), but it is also a matter of guaranteeing a form of accountability for the technological choices that are made and of maintaining a critical memory of the rationalities behind each choice.

Nuclear waste management programs and resulting closing up commitments in France and Canada illustrate how heterogenous temporalities have come (and will continue to come) into tension or conflict, given that the temporality of the political decision and that of the maturation of technological projects are rarely synchronous. Temporality is an interesting notion to consider in the future of nuclear waste governance because of the long life of HLRW that involves multiple generations well beyond the “current and near-term generations” envisaged in the Canadian APM approach. And further, because taking care of the legacy of closing up commitments such as the reversibility or retrievability of waste will require sustained attention to “operational temporalities” (Ialenti 2021) including schedule pressures and incentives to accelerate productivity of waste, cleanup staff, office employees, subcontractors, administrators, middle managers, regulatory compliance specialists, and other personnel—often at the expense of quality control.

The construction and operation of future storage sites for radioactive waste in France and Canada will bring to the forefront issues of operational temporalities, revealing deficiencies that may trigger nuclear waste accidents, as Ialenti showed in analyzing the 2014 nuclear accident at a transuranic waste repository in New Mexico (Ialenti 2021). These challenges imply a dedication to describe and intervene in the future of technological projects that will not always take the turn we would have liked to see and that will perhaps consecrate the domination of the state and of the structures of nuclear promotion and regulation. Our contribution is to have a closer and more pragmatic look at closing up, that is, to scrutinize the openings or asymmetric trade-offs that are introduced through participatory exercises and that are significant in the long run even after the particular technological and policy choice has been made.

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Notes

1. In Canada, the Atomic Energy Control Limited (AECL), and the Commissariat à l'Énergie Atomique (CEA, later ANDRA) in France.
2. In France, the Ministers of Ecology, Industry, and Research are in charge of such questions. In Canada, it is the Federal Minister of Energy, Mines and Resources and their equivalents at the provincial level.

3. This raises an important question, which is beyond the scope of this article: at what point does the permanent and easy possibility of soliciting support for the organization of a participatory event at any time have a dissuasive effect, leading to a spacing out of the moments of dialogue and meeting between the publics concerned?
4. The metaphor of conjugation as used by Hecht to refer to how sociotechnical practices affect (post)colonial power relations is interesting to address the asymmetrical power relations that result from a “closing up commitment”: “Conjugation transforms the meaning of a sentence by shifting its time frame or by changing who performs the action. Sometimes these are radical transformations, sometimes not. Conjugation thus enacts continuity and change simultaneously” (Hecht 2002, 693).

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