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Striving for technical consensus by agreeing to disagree: the case of monitoring underground nuclear waste disposal facilities

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ABSTRACT

Socio-technical arrangements seeking to produce consensus are understood differently by theories in science and technology studies. Some scholars argue that consensus ambitions are coercive in that they oppress the (inevitable) alternatives to the dominant values and interests that are enforced under a guise of consensual unity. Others argue that consensus is inherently characterized by value and interest heterogeneity, i.e. downplaying processes of coercion and exclusion, and instead emphasizing 'multiplicity'. In this article, we combine both these seemingly contradictory insights to understand how a European Union Research and Development Project sought to produce consensus among a range of international actors about introducing new technology into existing nuclear waste management programmes. By presenting the political and technical contexts of two national programmes – the Swedish and the French – we show that political and legislative preconditions for monitoring differed between the countries. The project thereby faced the European Union's expectations of honouring certain (political) values by producing consensus and the simultaneous turmoil of divergent national trajectories. This turmoil, however, was reconciled by 'agreeing to disagree'. By producing consensus on the level of technical protocols that allowed a degree of flexibility, both the political values of European harmonization imposed on the project and the integrity of the somewhat divergent national programmes were honoured. Fundamentally, we argue that the coercive aspects of this process are constituted by the naturalization of European Union policy, but that such coercive efforts still leave some room for diversity, i.e. flexibility.

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1. Introduction: the versatility of consensus

Nuclear waste management (NWM) is notoriously controversial. Whereas spent nuclear fuel was not at first considered a liability for nuclear power operations, during the last 50–60 years actors responsible in the field have acknowledged that the by-product is indeed *waste*. Considerable efforts have thus been invested to manage it. Among key actors – such as waste management organizations (WMOs) and governments – technical consensus has crystallized on the merits of

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geological disposal (GD). By disposing of the waste underground, safety is eventually to be acquired *passively*; no active measures by future generations should be needed to prevent radionuclides from migrating from the underground.

Still, the technical consensus on passive safety accommodates tension. Assessments regarding the degree to which it can manage nuclear risk are not entirely convergent among either publics or experts. One recent example of the (potential) renegotiation of passive safety is the proposition that *monitoring technology* can aid further in managing risk, thus promoting improved or additional safety to geological disposal. Monitoring partly challenges ideals of passive safety because it holds that managing risk – i.e. producing safety – should be an *active* effort also in the longer term. From this perspective, maintaining safety is a ceaseless and recurrent activity.

Can the two ways of managing risk be reconciled, or are they in fact incommensurable? In this article, we explore how the EURATOM Horizon2020 project Modern2020 (Development and Demonstration of Monitoring Strategies and Technologies for Geological Disposal) sought to integrate new monitoring technologies into existing national NWM programmes. The project did so within what we call 'the harmonization framework' of the European Commission's (EC) Research and Development (R&D) funding. Modern2020 was thus expected to produce *consensus*, or 'collective opinions on monitoring' (Modern2020 2016a, 2016b). This task nonetheless entailed negotiating contradictions in – and between – national political and legislative demands for NWM. Modern2020's attempts to reconcile active and passive safety were performed in a situation where there was dissensus and divergence. As we show in this article – and lying at the core of our analysis – risk reconciliation required specific commitments.

The call for consensus in R&D projects to address societal challenges and risk management raises certain questions. Why must consensus be achieved? Is there a problem with dissensus? If so, what are the problems? Is there 'one best' mode of safety or can the same level of safety be achieved by divergent means? Can divergent risk practices co-exist?

We approach these problematics by visiting science and technology studies (STS). In doing so, we argue that the boundary between *the political* and *the scientific* is not distinct. Hence, technical consensus has political implications. At its best, consensus building can be a collective exercise to effectively assess and conclude the validity of truth claims, thereby contributing to identifying 'best practices'. At its worst, consensus efforts might overlook that knowledge is uncertain, and that there might be a legitimate variety of actions available for acting upon it (e.g. Miller 2016). Funding programmes for R&D projects, such as those set up by the EC's Directorate-General for Research and Innovation (DG RTD) situate a striving for *technical consensus* not only in a context of science but also in a context of particular political values and controversial risk discourses, i.e. in a world with potential political and technological *alternatives*. It is crucial to analyse how political interests might drive consensus in order to make their claims naturalized, and to show how competing interests are offset when consensus is established and just 'the facts' remain (Horst and Irwin 2010).

Our first aim is empirical and serves to explicate what national political and legislative demands enabled, as well as restricted, the introduction of monitoring technologies into existing programmes, as well as to understand how the Modern2020 project attempted to reconcile these differences within a consensus framework. For that purpose, we zoom in on two telling national NWM programmes, the French and Swedish, examining their specific national contexts as well as their roles in Modern2020.

Our second aim is theoretical and serves to improve our understanding of how consensus efforts, such as European harmonization in relation to R&D work, might conserve predominant political values and technologies while *simultaneously* allowing the coexistence of competing values. In doing so, we critically engage with and combine two different understandings of the implications of consensus in STS. We analyse these two understandings as emphasizing, on the one hand, *coercion,* and on the other hand, *flexibility*. We build our analysis on a combination of both to understand the consensus that emerged in Modern2020.

In what follows, we first address the theoretical conceptualizations of scientific consensus that have been important focal points for STS (Section 2). We then account for the EC's previous efforts to harmonize the field of NWM and we introduce the Modern2020 project and the authors' role in it (Section 3). This is followed by an empirical account of how the convergence and divergence of two national programmes created both opportunities and restrictions for (technical) consensus within Modern2020 (Section 4). Lastly, we discuss our improved concept of technical consensus (Section 5).

2. Coercion and flexibility as two distinctive roots to scientific consensus

Truth claims cannot be verified solely by reviewing the objective characteristics of the knowledge on which such claims rest. Whereas modernist depictions of science plead that science follows a path of disinterested progression and objectivity divorced from cultural elements of humans, Kuhn's (2012) study on scientific paradigms made clear that even science constitutes a cultural domain. One example of social practices that characterizes scientific work – which Kuhn highlights – is the striving for *consensus*. This insight has inspired STS, which elaborates how scientific cultures, as part of their ambition to authoritatively display agreed knowledge, simultaneously establish social cohesion and cultural boundaries for competing groups and wider society (Jasanoff 1990; Collins 1992; Gieryn 1999). Therefore, group formation is an important part of creating consensus (Collins 1992, 159) in order to present results (or indeed knowledge) as 'natural' and 'inevitable', i.e. without alternatives.

This means that when there is no consensus on the properties of objects or technological artefacts – e.g. in the case analysed in this article a nuclear waste repository's integrity – they are not naturalized but open to interpretation. An artefact's characteristics (e.g. repository safety) are in such instances seen as in need of explanation, rather than being 'intrinsic properties', taken for granted (Bijker 1995, 75). Different conceptions of artefacts may be in conflict, and actors may seek to naturalize particular views at the expense of others.

Thus, consensus efforts potentially come with a price, because certain social interests might come to dominate others when naturalized. Expressed differently, scientific data or concepts are always defined 'in terms of an (implicit or explicit) framework of premises and purposes of some kind … backed up by a structure of social control' (Wynne 1975, 123, 126). Producing consensus is often more complex and less innocent than merely stacking indisputable facts on top of each other.

The *application* of scientific facts and development of technology additionally stresses this complexity. Applied research in fields such as nuclear energy and the environment operates in broader cultural, commercial and political contexts than scientific institutions generally do (Garrety 1997; SAPEA (Science Advice for Policy by European Academies) 2019). NWM, for example, is situated in controversial risk debates, and is politically and economically contingent. In such fields policy often comes *first*, followed by R&D to substantiate the policy, which testifies to the interdependency of the two (Jasanoff 1990).

Reaching scientific consensus is therefore also a 'political act' of reconciling and/or choosing between competing interests (Horst and Irwin 2010). While we here have described the problems of consensus in rather abstract terms, it illuminates the reality that Modern2020 faced. The project invoked consensus ideals similar to those of science, but there was also a political rationale – as well as consequences – for invoking such ideals. Essentially, the emphasis on technical consensus on how to integrate monitoring concealed the more politically laden processes, which we set out to make more tangible.

However, in the field of STS we find two distinctive perspectives on how to move from competing interests to consensus in science and particularly in the development of technology. The first perspective describes consensus as *coercive*, because consensus forces divergent actors to conform to hegemonic values despite the existence of potential alternatives (Wynne 1975). From this perspective, scientific consensus is seen as the result of processes of *eliminating* such alternatives. Who has the privilege of interpretation in these instances – i.e. who defines 'desirable' social goals and determines 'what is the problem' – is thus worth taking into account. When there is conflict over problem descriptions, Wynne asserts that to assume that consensus exists, 'and act as if it did, is a form of political coercion' (1975, 141). From this perspective, scientific and even more so technical work also entails internalizing and rationalizing political interests.

However, a sole focus on how alternatives are eliminated overlooks that coercion sometimes needs to *negotiate* also with more marginalized interests. Such interests may therefore influence consensus arrangements. This means that coercion often exists in milder forms that allow for a certain degree of flexibility. Coercion does not produce complete conformity. Ironically, a degree of technological and political flexibility, i.e. the *inclusion* of divergent values (or principles for managing risk), can be a necessity for preserving dominant institutional values.

To accommodate also this aspect of flexibility, we find another STS approach concerned with *multiplicity* and *coexistence* of technological and political divergence. Often referred to as 'boundary studies', it implies that conformity seldom is the outcome of consensus arrangements. Rather, it downplays the significance of coercion and power, stressing that there is indeed flexibility in consensus arrangements. When elimination of alternatives is not seen as the key mechanism for producing consensus, the focus is put not only on communication within expert groups, but also on communication with outsiders, and on extension of the notion of 'expert group'.

Boundary studies has become one of the most influential streams in STS, employing concepts such as 'boundary work' (Gieryn 1999) 'boundary organisations' (Guston 1999), 'boundary objects' (Bowker et al. 2016), 'trading zones' (Galison 1997; Gorman 2010) and 'interactional expertise' (Collins and Evans 2015). These concepts indicate a possibility of communication across paradigms to facilitate understanding between culturally divergent actors. Technology development from this perspective we understand as implying a certain degree of *flexibility*; consensus arrangements do not merely eliminate alternatives.

From this consensus discussion, the objective becomes to empirically investigate what can be described as coercive, *and* what can be described as flexible. The theoretical framework can be summarized as resting on four elements. The analysis seeks to show: (i) how technical consensus is achieved – at least partly – by getting rid of alternatives while making the remaining knowledge 'natural'; (ii) how technical consensus internalizes external (political) premises and purposes as technical details; (iii) how communication can be established across cultures with different preconditions to establish consensus that allows for flexibility; and (iv) how flexibility in consensus arrangements might be a necessity for safeguarding dominant interests.

3. EC-funded R&D in the field of NWM

EC-funded R&D projects are understood as financial instruments designed to address societal challenges and to contribute to the 'EU's blueprint for smart, sustainable and inclusive growth and jobs' (Horizon2020 2020). Besides growth, 'harmonization' is a key ambition for the EC. According to the harmonization framework of European Union (EU) R&D, the object is to identify so-called 'best practice', to develop and disseminate technological standards across the EU (EC (European Commission) 2020a, 2020c). A harmonized EU technical infrastructure is understood as serving values of efficiency and competitiveness (EC 2020b). EC-funded R&D projects are expected to act in accordance with these values, and to contribute to harmonization.

Simultaneously, addressing societal challenges is rarely a harmonious effort. One often encounters varying interests and perceptions between countries, and between different groups within – or across – countries. Important fora in the EU for addressing and overcoming these challenges

– through the simultaneous ambition of technological innovation as well as consensus building – are so-called European Technology Platforms (ETPs) and European Technology and Innovation Platforms (ETIPs). ETPs are industry-led frameworks seeking to produce a common technological vision for addressing particular challenges and a subsequent 'Strategic Research Agenda' (SRA) for implementing a particular technology. ETIPs, in turn, are led by research and funding institutions, and seek to define strategic paths for new technology development. Both have the explicit aim to foster interaction and cooperation between a multitude of stakeholders, ranging from business and academia to policymakers at various levels, public authorities and civil society organizations (Martell and Bergmans 2012), making them a melting pot of science, technological innovation and policy.

There is currently a range of ETPs addressing a variety of challenges, not least within the field of environmental risk. One example is the Sustainable Nuclear Energy Technology Platform, which seeks to 'combat climate change by means of R&D in the field of fission' (SNETP 2021). Typically, ETPs integrate certain values, such as European competitiveness and efficiency of production, with the management of environmental risk.

The striving for technical consensus in EC R&D aligns with the ideal of consensus in scientific work and its modernist air of objectivity, but simultaneously originates from political ambitions. The consensus ambition to forward political values and corresponding technology in EC R&D projects raises the question about the prospects of exhausting potential political and technological alternatives. Wynne's warnings about coercive aspirations are not without merit because, clearly, ETPs are not unconditional; at least, to some extent they are the product of predefined policy.

NWM is a good example of the intermixture described above. Its risk issues have notoriously yielded controversy, as has its relation to broader controversies about nuclear power. Indeed, 'solving' the waste issue is often assessed as key also for 'public acceptance' of nuclear new build. The principle of passive safety (i.e. that no active intervention should be needed once repositories have been sealed) is one example of previously harmonized risk management. It is the foundation of a particular ETP, the Implementing Geological Disposal Technology Platform (IGD-TP), launched in 2009 (IGD-TP 2015). In 2011 a new *EU Directive* on spent fuel and radioactive waste was established (EU (The Council of the European Union) 2011), additionally stressing the ambition of the IGD-TP to harmonize national waste policies in the EU, and presenting GD as an international consensus solution – 'the safest and most sustainable option' – for final disposal of nuclear waste.

3.1. Premises and purposes of the IGD-TP

The IGD-TP was launched to build confidence in GD and passive safety among citizens and decision-makers in Europe. The platform's initial vision was to achieve the first operational repository in Europe by 2025 (EC (European Commission) 2009). Its key formulation was 'it is time to proceed'. With this goal, the IGD-TP has played a key role in establishing the EC R&D agenda in NWM. It is at this level that an SRA was developed, which subsequently has fed the programming of calls for research funding within the Horizon2020 framework. In its first SRA (2011) the IGD-TP identified remaining challenges that must be overcome before safe operation of waste repositories can be achieved. One such challenge was monitoring (EC (European Commission) 2011, 40). Hence, we focus in this article on that first SRA.

The IGD-TP's vision is explicitly political, stating that research is a tool for solving remaining challenges, including building public confidence, for which monitoring is seen as instrumental (EC (European Commission) 2004). Consequently, developing monitoring strategies is of importance. International standards and guidelines – such as those of the IAEA. (2001, 2014) – prompt national waste programmes to present such strategies. Monitoring in this respect has become an issue of priority in many NWM programmes (Kuppler and Hocke 2019). However, monitoring can encompass many different things and ranges from collecting environmental data to monitoring the very inside of a repository. The latter becomes a particular challenge, because facilities are located hundreds of metres below ground, eventually sealed off, while continuing to perform their function for hundreds of thousands of years.

Repository monitoring partly challenges passive safety, as monitoring promotes ceaseless and active improvement of safety through continuous surveillance of certain parameters inside a repository. Because of its potential incompatibility with passive safety, it has remained for a long time out of scope. However, as plans for building GD facilities have become more concrete, demands for more flexible and cautious approaches have grown. The legal obligation of reversibility – the possibility to reverse certain decisions and actions – has become of great importance in countries such as France and Switzerland. Additionally, the idea of installing monitoring equipment within repositories has been strengthened by the development of new technologies such as wireless sensors (Bergmans et al. 2012). Nonetheless, demands and possibilities for monitoring differ between countries, depending on political and geological conditions, as shown in the next section. If member countries end up choosing contradictory technologies for upholding safety risks, it would strike a discordant note in the (alleged) harmony of technical convergence vis-à-vis GD (see e.g. IGD-TP 2011, 2016). Hence, the EC and IGD-TP have seen a need to consider the challenge of monitoring, and have done so by instigating collaborative work and coordination by R&D.

3.2. Modern2020: paving the way for technical consensus on repository monitoring?

A response to the ambition to reach technical consensus on repository monitoring was the EU-funded research project Modern2020 (2015–2019). Modern2020, and its forerunner MoDeRn (2009–2013), aimed 'to provide the means for developing and implementing an effective and efficient repository operational monitoring programme' (Modern2020 2014, 4). This ambition can be interpreted as an attempt to coordinate national programmes' monitoring efforts, i.e. harmonization. The two projects also promoted 'taking into account the requirements of specific national programmes' (2014, 4).

Modern2020 consisted mainly of technical experts, related to nuclear waste management organizations (NWMOs), dedicated national NWM research institutes or technical support organizations, academic research units and specialist consultants.[1] As is often the case with such R&D projects, ambitions go beyond mere technology development. Although emphasis was put on scientific and technological improvement, Modern2020 also aimed for 'development and evaluation of ways for integrating public stakeholders' concerns and societal expectations into national repository monitoring programmes' (Modern2020, 2016b). Consequently, social scientists (represented by the authors of this paper) joined the project, and invited citizens from communities hosting (or aspiring to host) NWM facilities. Citizens were encouraged to partake in meetings and project workshops, to interact with members of the consortium, to reflect on the projects' goals and developments and to share their expectations regarding repository monitoring (technology).

Other than contributing to the project's ambition regarding responsible research and innovation, the authors' role was to conduct research on the project itself. This paper is part of this latter ambition. Methodologically, it is primarily based on participant observation in international project meetings during 2015–2019. This includes discussions with consortium members, but adds also a secondary analysis of an internal survey on national monitoring strategies carried out by one of the project partners. Taken together, this material allowed us to study how the project's consensus emerged over time and the practical work that the partners had to undertake to reconcile activity and passivity. Moreover, a crucial part of the empirical material is constituted by national legislative frameworks, primarily those guiding France and Sweden. This material served to highlight the rather divergent national legislative demands. Lastly, an analysis of an online interactive survey on the relation between monitoring and repository governance, directed at both project partners and participating citizens, was included to emphasize the divergent views on monitoring harboured both within and between lay and expert groups.

4. Striving for technical consensus in practice: lessons from Modern2020

4.1. National differences and disharmony

National legislative and policy frameworks produce different possibilities for the introduction of monitoring technology. The cases of France and Sweden – both being among those closest to implementing GD (Anshelm and Galis 2011; Barthe, Elam, and Sundqvist 2020; Di Nucci et al. 2015) – provide good examples, and explain the differences in interest and approach of the respective NWMOs in the Modern2020 project.

Starting in Sweden, we now illustrate how national legislative and political conflicts condition the introduction of monitoring technology. In Sweden a license application to build a final repository for spent nuclear fuel in the Municipality of Östhammar, which already hosts three reactors and a final repository for short-lived radioactive waste, was sent to the government authorities in 2011 and is still under review (Barthe, Elam, and Sundqvist 2020). The Swedish KBS concept (short for KärnBränsleSäkerhet – Nuclear Fuel Safety) is based on final disposal of non-reprocessed spent nuclear fuel and consists of three safety barriers: the encapsulation of the waste (the copper canister), the buffer material (bentonite clay) and the bedrock (crystalline rock).

Crucially, these barriers are intended to uphold passive safety, which is the core of KBS. Passive safety is the international norm, but the Swedish national regulator, the Radiation Safety Authority (SSM), emphasizes this most explicitly by stating in its legislation not only that ‘the integrity of a future repository should rely on a system of passive barriers’ but also that ‘monitoring can be considered only if it does not impair passive safety’ (SSMFS 2008, 21).

This must, however, be understood in light of past national political conflicts. The call for ‘absolute safety’ of how and where to finally dispose of spent nuclear fuel was first introduced in the so-called Stipulation Act from 1977 (SFS 1977, 140). The Act linked permission to fuel new reactors to ‘absolutely safe’ handling of the nuclear waste. This was a way for the government to reconcile the deep divide between pro- and anti-nuclear forces in Sweden, leading up to a national referendum on the future of nuclear power in 1980. Political parties, including within the government, disagreed widely about nuclear power, but finally agreed on the importance of high safety standards for NWM. However, anti-nuclear parties interpreted these requirements as setting unachievable goals for nuclear power, while pro-nuclear parties assessed the standards as attainable (Sundqvist 2002, ch. 4).

The nuclear industry sought to meet the Act’s high standards and reacted to the legislation by founding the Swedish Nuclear Fuel and Waste Management Company (SKB), with the core purpose of conducting R&D. Within a year of the Act’s approval by the national parliament, the multi-barrier KBS system was presented as a technological solution to the waste problem, i.e. as ‘absolutely safe’ (Sundqvist 2002, 79). The new and strong political focus on *safety* transformed political conflicts about energy futures into discussions about believing or not believing in the safe disposal of nuclear waste.

In 1984, the Stipulation Act was replaced by new and still existing legislation, where the wording ‘absolute’ was removed. Instead, the new objective was to ‘safely handle and dispose of the radioactive waste’ (SFS 1984, 3). The shifts that the legislations of 1977 and 1984 contributed to – from parliamentary and extra-parliamentary political conflicts to a more technical focus to achieve safety – have given technical experts in NWM a key role also in discussions about – and decision-making on – the future of nuclear power. Ever since the new laws were introduced, the waste issue has been treated as a technical matter for the implementer (SKB) and the regulator (SSM) to evaluate.

As monitoring technologies in NWM have in recent decades been increasingly emphasized outside of Sweden, SKB has raised concerns about the *dangers* monitoring might pose to passive safety. The content of this concern, expressed by SKB in a survey performed at the beginning of Modern2020 (Modern2020 2015), is, firstly, the risk of foreign technology 'compromising the integrity of the barriers'. Secondly, the uncertainties associated with monitoring technology may, according to SKB, render false readings and inaccurate signals. This is not a position unique to SKB, but SKB tends to reiterate its concerns more frequently and extensively than its international equivalents. SKB holds that monitoring technology must be used particularly restrictively, because: 'clearly any monitoring impacting the safety of the barriers must not be used in the real repository. This means that some solutions used in the labs (cables, destructive testing…) may not be used in the repository'. According to SKB, monitoring technology presents more difficulties when introduced in practice, as: 'inaccurate signals could, in the worst case, lead to unjustified decisions about various measures, such as to retrieve the canisters, which would be associated with high costs, and radiological hazards for workers involved in the process'.

SKB thereby finds itself in an ambiguous situation. On the one hand, monitoring appears to NWMOs in other countries and to some public groups, in Sweden also, as an enhancement of safety, which puts a certain pressure on implementers to add monitoring to their safety repertoire. On the other hand, the demands for monitoring stand in conflict with national political and legislative demands in Sweden. Monitoring and active safety fit poorly with the ambition to achieve passive safety – at least, how such safety is sought in Sweden – but is also in conflict with the idea of mediating political conflict by technological means. Since monitoring signals that the notion of safety is, at least potentially, in need of continuous updating and revision, the Swedish legislative demands of calculating a priori the measures needed to uphold (passive) safety means that the ambition to recurrently assess safety by means of monitoring is somewhat out of place.

To make this last point clearer, the Swedish legislative stipulations and their impact on what type of monitoring measures actually can be performed within the Swedish framework of existing legislation can be contrasted with these of France. In 1979, the French government appointed the National Agency for Radioactive Waste Management (ANDRA) as the government agency tasked with managing France's nuclear waste. Since 2000, ANDRA has been developing the *Centre industriel de stockage géologique* (Cigéo), a facility for nuclear waste disposal in line with French legislative requirements, in the vicinity of the nation's only underground research laboratory for GD in the community of Bure. ANDRA is currently preparing an area covering a 30 km radius for a licence application to construct Cigéo. This work is under recurring review by the nuclear safety authority, Autorité de Sûreté Nucléaire (ASN).

Imprinted in legislation since 1991, the requirement of 'reversibility' is central to the French GD concept. Reversibility entails the possibility to retract the waste from underground even after disposal (Barthe, Elam, and Sundqvist 2020). The Law of 25 July 2016 on reversibility and governance (Act No. 2016-1015 2016) defines the concept of reversibility and sets an agenda for regular public meetings to discuss project governance. As such, future generations are given the opportunity to either continue the construction and operation of geological storage or to reassess previously made choices in NWM and find new solutions for disposal. In that respect, reversibility refers not only to the repository facility, but also to *decisions* that impact on environmental risks.

The introduction of reversibility in the French programme was an effort to handle strong political conflicts in NWM. During the 1980s, a broad research programme on nuclear waste focusing on different technological options was transformed into a targeted industrial project, led by ANDRA, to implement GD by investigating four different sites. From 1987 to 1990, these plans generated strong political opposition to the technological solution, the lack of information and the opaque decision-making process (Barthe, Elam, and Sundqvist 2020). Essentially, the new legislation and its emphasis on reversibility was a way of mediating the political controversy, and can thus be understood as a political tool for conflict resolution.

Reversibility requires that the French GD system be able to adapt to changes in energy policy, regardless of whether that involves stored waste being taken out (potentially redefined as a resource) or redesigning the facility to accommodate new categories of waste. It requires that the operation of a repository must begin with a pilot phase to consolidate reversibility and demonstrate the safety of the facility (Act No. 2016-1015 2016). During this phase, all waste packages must remain recoverable. Hence, the French programme makes an explicit distinction between the notions of 'reversibility', which puts emphasis on the flexibility of the process, including the concept and the design of the facility, and that of 'retrievability', i.e. recovering the waste (OECD-NEA 2012).

However, the long-term aim is passive safety, since the reversibility requirement only applies to the operational period, which constitutes some 100 years after which the repository is to be fully closed. For the remainder of its 100,000-year lifespan, the repository facility is intended to be progressively irreversible.

Reversibility has a clear connection to monitoring; a decision to reverse the emplacement process will need some form of supervision. In contrast to the Swedish auditor, ASN explicitly demands a monitoring and surveillance programme that includes systematic measurements in order to control the construction, operational performance and the phase after closure, and to ensure that the repository evolves as expected and that the defined monitoring parameters remain within 'acceptable limits' (ASN 2008). ANDRA (Modern2020 2015) envisions this as supporting incremental learning about the behaviour of the GD in a 'stepwise approach', to inform future R&D activities. Repository monitoring, it is argued, could contribute to incremental learning, leading to amelioration of the repository concept, as well as safety.

Just as in Sweden, the French concept has been adapted according to political conflict. Fundamentally, a 1991 law entailed a legislative rearrangement of NWM, concerning both technological concepts and decision-making. This change was also an explicit way to deal with political conflicts. While Sweden focused on a rigid technical framing of the nuclear waste issue to overcome conflict, France has built in a certain level of flexibility into its programme to meet public demands for potentially redefining the scope and function of a future repository. The principle of reversibility is the most prominent example, which is simultaneously a political and technical solution to conflict. The outcomes diverge, but their bases are in both cases political.

While the Swedish case displays certain limitations to the introduction of monitoring, monitoring appears to be more easily integrated into the French programme. The size of the French nuclear programme and the assumption of its continuation, together with an explicit role for political decision-making in the various stages of building, operating and closing a repository facility, furthermore makes the operational phase more visible and the need to show all is running as planned more tangible. Monitoring is in this context an integral and indispensable aspect of repository technology. Thus, monitoring technology suits political preferences already internalized within the programme.

We can thereby conclude that the prerequisites for monitoring are not a strictly scientific or technical issue. Anyone who seeks to develop a monitoring programme will thus face the divergent political demands internalized within existing programmes. As the Swedish and French cases show, these are not always fully reconcilable.

4.2. Reconciling conflict: technical protocols

How did Modern2020 reconcile the tensions between the programmes? Clearly, consensus would have to be established in spite of, or by leaving room for, national differences, by 'illustrating how the national context can be taken into account in designing dedicated monitoring programmes' (Modern2020 2014, 4).

Throughout the project, the actors sustained their disagreement on monitoring and were in conflict over seemingly simple questions such as 'why', 'what', 'when' and 'how' to monitor. There were different views on whether monitoring could contribute to safety, transparency and decision-making. The actors' national legislative frameworks both enabled and restricted them with regard to what type of monitoring could actually be performed; what was possible in one context was impossible in another. Despite experts' joint technical language, the problem of *how* to integrate monitoring still remained. A few countries feared that the more monitoring-friendly countries would set a monitoring 'gold standard'.

Simultaneously, it did not suit the consensus ambitions to remain in disagreement; 'we have to move forward now', as a coordinator repeatedly said when the group lingered in disagreement. The NWMO representatives explicitly acknowledged the disagreement, but agreed to seek 'lowest common denominators'. The model monitoring programme would have to be designed so that it would not force itself upon national programmes.

Whereas the monitoring ambitions from the start had been more extensive, the partners successively reduced their scope. The lowest common denominators eventually crystallized as *flexibility* and *procedure*. This had an easing effect on the members who previously had feared the diffusion of a comprehensive monitoring standard. Still, the actors had to discuss at length in order to arrive at a concrete solution. After extensive negotiating in an array of meetings, get-togethers, conferences, telephone conferences, e-mail correspondence and so forth, it was time to make advancements and move towards 'collective action' and consensus.

The solution was technical. In practice, consensus was achieved (i) by the production of a so-called 'generic iterative workflow' for developing and undertaking a repository monitoring programme; (ii) by adding the 'Modern 2020 Screening Methodology' – a generic method for selecting monitoring parameters, i.e. *what* to monitor (e.g. temperature, pressure and oxygen concentration) – that was tested in seven different cases (Modern2020 2019, 28–29); and (iii) by developing a set of recommendations and guidance on planning for evaluating and responding to monitoring results, including 'generic responses' that could be invoked in response to monitoring results (e.g. evaluate sensor performance, check results, report results and change operations) (Modern2020 2019, 30–34). Crucially, the methodology does not prescribe particular *actions*, but a particular *procedure*:

> The Methodology is intended to be indicative and flexible rather than prescriptive, and can be regarded as a template that can be adapted by individual WMOs to suit particular needs. Flexibility includes, for example, the possibility to modify the starting points and approaches as appropriate for each waste management programme. (Modern2020 2019, 30)

From the viewpoint of STS, this solution is a technical device that serves political functions. By delivering a framework for developing consensus, the actors could agree on procedure, and omit outcome. This remedied the tensions between national legislation by creating consensus on *flexibility*. It coordinated multiple contradictory risk management principles not solely by processes of elimination. When determining *why, what, where* and *how* to monitor, representatives of national NWMO's can feed sociotechnical data into the workflow, i.e. needs that may be invoked with reference to national and/or local publics' demands.

At the end of the project, the conclusion was that substantial advances had been made in 'developing new, or adapting existing, technologies', but that 'further research is required to fully bring these technologies into practical use in an industrial setting' (Modern2020 2019, VI). Modern2020 also held that 'there is a broad consensus for the guidance, tools and approaches proposed within the Project' (Modern2020 2019, 39).

These technical endeavours were attempts to internalize and take control over the growing attentiveness to monitoring capabilities produced by novel technology and public concerns.

However, as our analysis shows, national trajectories and political contexts far from always allow for technical convergence, i.e. harmony. The different political and legislative national requirements illustrate this, but also the dominance of the technological consensus that surrounds GD.

Despite acknowledging differences, technological diversity is still seen as problematic; a certain level of harmony is desirable despite the 'flexibility' of Modern2020. Safety is presented as unidimensional despite the clear national differences in trying to achieve it. According to Modern2020 (2014),

> [monitoring] can contribute to public and stakeholder understanding of processes occurring in the repository, and hence, it can respond to public concerns and be used to build confidence in geological disposal. Monitoring therefore plays an important role in enabling waste management organisations to work towards the safe and accepted implementation of geological disposal.

Despite the differences of NWM programmes in assessing the safety that monitoring may or may not bring, monitoring is here represented as a tool for confirming passive safety. What is up for debate is thus not principles of NWM, the future of nuclear power or EU energy policy. These are invisible *premises* of the development of monitoring technologies; they are internalized as a rationale for the project of harmonizing the assessment of monitoring technologies in the safe implementation of GD.

Modern2020's ambition was to communicate a common technical solution, i.e. consensus, despite disagreements on how to achieve safety. Modern2020's technical protocols, a one-size-fits-all solution, is now a resource for European national waste programmes to show that they apply a universal monitoring approach. Sweden and France expressed opposing views when the project started, but now display converging views on the level of protocols on how to conduct monitoring. To be sure, national differences remain but are now coordinated by technical standards; EU ideals of consensus are rhetorically conveyed with a simultaneous perpetuation of the dissonance Modern2020 set out to harmonize.

5. An improved understanding of consensus

For decades, political actors and technical experts have claimed that GD is safe and ready to implement. During the last decade, this position has been advanced by the EU. However, the ways of establishing safety are not entirely convergent and do not give a conclusive answer to the question of how we should, or should not, develop repository monitoring as part of safety strategies. Moreover, new monitoring technology partly contradicts 'old' consensus on GD, which in turn serves an important function for EU energy policy and the legitimization of nuclear power new build. This was the situation to be handled by the Modern2020 project.

How, then, are we to understand the nature of the consensus that eventually emerged? The work carried out with regard to monitoring on the EU level is coercive in that it forwards a set of social interests and political values by means of technical consensus. It perpetuates already negotiated (controversial) policies and locked-in technologies, and reinforces what has already been achieved politically and technically in national programmes. It does so at the expense of potential political and technological alternatives. Modern2020 did not unlock the locked-in principles of e.g. 'competitiveness' and 'efficiency' invoked by the harmonization framework of the EU. Instead, it naturalized them by presenting them as resting on consensus, thus evading a wider debate on ethical principles of responsibilities, judgments of acceptable risks, and nuclear new build. Yet, the Modern2020's consensus simultaneously accommodates diversity. Apart from the naturalization of the values mentioned above, it also provides the opportunity for its users to *respond* to public and legislative demands, i.e. to *different* national political contexts. There is not merely coercion, but also the flexibility to take into account divergent demands posed by national legislation, and indeed publics.

While flexibility *can* be understood as a democratic advantage over more coercive measures, it is important to highlight that flexibility in the case of Modern2020 was simultaneously a means to preserve the status quo of GD and EU energy policy. Importantly, it tells outsiders – such as lay publics – that monitoring is now integrated into all national EU NWM programmes and that GD can be implemented on common and safe grounds while allowing NWMOs to proceed according to (somewhat divergent) national trajectories.

As an example of the concrete political results of the specific consensus achieved by Modern2020, at the end of the project, SKB had gone from being largely opposed to monitoring to accepting the Modern2020 monitoring protocols. SKB came to promote the flexible monitoring technology, although largely maintaining the same sceptical stance towards monitoring. Nothing essential had changed with regard to demands for monitoring in Swedish national legislation and regulations.

6. Conclusions

An important task for STS scholars is to make explicit the implicit political interests underpinning technology, e.g. that nuclear power and NWM are politically important. Political assumptions and commitments exist both when technical solutions imply coercion and when flexibility is allowed. Our study of monitoring on the EU level displays both *coercion* and *flexibility*. As such, our analytical ambition to focus on the specific mix of coercion and flexibility can be seen as a call to more accurately describe and understand the technological and political implications of such mixes in concrete consensus arrangements.

Finally, STS inspired analyses are important, since they provide insights into political contexts that feed into technology development. This entails showing how technical activities, involving different levels of *coercion* and *flexibility*, are driven by political assumptions and commitments and, thereby, involve strategic manipulation of naturalizing them. Such efforts include reflecting on what interests are best served and reinforced by the technical work. This is of special interest to governance processes dealing with long-term planning, such as for nuclear waste (Kuppler and Hocke 2019), but as we have shown in this paper, this is far different from what is taking place in practice. The consensus rhetoric of the EU conceals both its coercive tendencies as well as its flexible tendencies.

Note

1. See http://www.modern2020.eu/about/partners.html (accessed 10 June 2021).

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