Conditional Progress

Technical Rationality and Wicked Problems in Nuclear Waste Management

Hannes Lagerlöf

UNIVERSITY OF GOTHENBURG

Department of Sociology and Work Science

Department of Sociology and Work Science
University of Gothenburg
Box 720
SE 405 30
Sweden
hannes.lagerlof@gu.se

Conditional Progress: Technical Rationality and Wicked Problems in Nuclear Waste Management
ISBN 978-91-87876-55-4 (PRINT)
ISBN 978-91-87876-56-1 (PDF)
Online: http://hdl.handle.net/2077/76012
Cover illustration: Hannes Lagerlöf assisted by Dall-E 2

Göteborg Studies in Sociology No 75
Department of Sociology and Work Science, University of Gothenburg

Trycksak
3041 0234

Printed in Borås, Sweden 2023
Printed by Stema Specialtryck AB

Abstract

While various states and enterprises have produced nuclear power for decades, that is, demonstrated the functionality of the nuclear fuel cycle from uranium mining to power production, the waste that is simultaneously produced has been provisionally stored awaiting a safe solution. Still, no country has implemented such a solution.

Nuclear waste is both dangerous and notoriously controversial, implying a range of social and technical problems. However, according to prevailing assertions in nuclear waste management (NWM), lingering concerns have now been addressed and definitive solutions are ready to be implemented.

In this thesis, I problematize these claims. By asserting that NWM constitutes a 'wicked problem' – that is, a problem to which there is no 'silver bullet' solution, only a set of suboptimal options to choose from – my ambition is to produce knowledge of that which has remained unsolved, de-emphasized, sacrificed, or even suppressed as NWM has progressed. Rather than understanding NWM as progressing because it has *solved* remaining problems, I ask how progression is possible *in spite of* the insolubility of these problems.

Points of departure like my own are marginal in previous research. Albeit sometimes critical, research has far from exhausted critical perspectives readily available for social scientists. I argue that such concepts are a viable future research route. To contribute to formulating a more critical research path, I turn to science and technology studies (STS) because this field contemplates a broader range of sociotechnical issues than does most NWM research. However, STS has increasingly come to elaborate theoretically on instances in which sociotechnical configurations are made unstable, change occurs, and actors challenge taken-for-granted scientific facts and technologies. My core observation is that such a focus downplays the significance of stability and inertia, which I hold to be far more prevalent phenomena in NWM.

With a few caveats, I propose that these aspects of NWM can be understood using 'critical constructivism', that is, an alloy of the Frankfurt School's critical procedure and STS. By emphasizing the critical legacy of critical constructivism – primarily by borrowing the concept of 'technical rationality' – I argue that NWM's progress can be understood in new ways.

Empirically – by means of participant observation and textual analysis – I engage with four NWM sites, both locally and internationally. In Study I, we study how contradictory social interests in NWM were concealed by means of *technical* consensus and the production of *technical*

standards at the European policy level. In Study II, I seek to understand why a scientific controversy over copper corrosion remained the main issue in a Swedish court of law for technical and nontechnical actors alike, and why the broader implications of nuclear power and NWM were not made explicit. In Study III, I analyse the Swedish nuclear industry's tactics to secure consent in order to prevent opposition in a local community where a final repository for spent nuclear fuel will be built. In Study IV, we analyse how internationally influential implementers conceive of public emotions, and how implementers foresee the transformation of public emotions to facilitate the implementation of repositories.

On an aggregate level, the individual studies together show the ways in which NWM – in order to implement geological disposal – depresses and excludes reasonable objections that could challenge NWM's biases or expose its historical contingencies and preconditions. In the prevailing culture of NWM and its technical rationality, one of the few areas in which critique is still seen as legitimate is in strictly *technical* domains. The scrutiny of scientific and technical detail is recognized as viable because of its association with technical rationality, taking precedence over other forms of critical procedures based on, for example, the lived experience of technology and/or ethical concerns. A core conclusion that I draw, and that is enabled through the deployment of critical constructivism – is that the material nature of nuclear waste has rendered *irreversible* damage to the prospects of achieving change in the field.

Keywords: nuclear waste management, science and technology studies, critical constructivism, sociology, technical rationality, reification

Contents

List of studies

Study I

Lagerlöf, H., Sundqvist, G., & Bergmans, A. (2022) Striving for technical consensus by agreeing to disagree: The case of monitoring underground nuclear waste disposal facilities. *Journal of Risk Research*, 25(5), 666–679.

Study II

Lagerlöf, H. (2023) Swedish nuclear waste management as an inert controversy: Using critical constructivism to understand cold technological conflict. Accepted in *Science as Culture*.

Study III

Lagerlöf, H. (2023) Consenting publics: Fair nuclear waste repository siting? Published online ahead of print in *Environmental Politics*, DOI:10.1080/09644016.2023.2172867

Study IV

Lagerlöf, H. & Pettersson, J. (2022) Aligning Subjective and Objective 'Truth' in Nuclear Waste Management: On the New Role of Emotions in Contemporary Repository Siting Policy. Unpublished manuscript. To be resubmitted to *Emotions and Society*.

Abbreviations

ANT	Actor-network theory
EC	European Commission
EU	European Union
FEP	Features, events, and processes
FUD	Research, development, and demonstration (forskning, utveckling, och demonstration)
IAEA	International Atomic Energy Agency
IGD-TP	Implementing Geological Disposal Technological Platform
IPCC	Intergovernmental Panel on Climate Change
KASAM	Swedish National Council for Nuclear Waste
KBS	Nuclear Fuel Safety (KärnBränsleSäkerhet)
KBS-3	Nuclear Fuel Safety (third version)
KTH	Royal Institute of Technology (Stockholm, Sweden)
NEA	Nuclear Energy Agency
NWM	Nuclear waste management
OECD	Organization for Economic Co-operation and Development
RWM	Radioactive waste management
SNF	Spent nuclear fuel
SKB	Swedish Nuclear Waste and Fuel Management Company (Svensk kärnbränslehantering AB)
SFS	Swedish Code of Statutes (Svensk författningssamling)
SOU	Official Reports of the Swedish Government (Statens offentliga utredningar)
SSM	Swedish Radiation Safety Authority (Strålsäkerhetsmyndigheten)
STS	Science and technology studies
WP5	Work Package Five

Förord (Acknowledgements in Swedish)

I denna den mest lästa delen av en avhandling vill jag först säga att jag är intresserad av ganska många olika saker och berätta varför jag tror att så är fallet. Efter att ha skrivit denna avhandling tror jag mig nämligen veta lite bättre varför jag ofta ”hoppat” mellan olika intressen.

När jag exempelvis hoppade till fotografi, i början, styrdes jag inte nämnvärt av några konventioner. Inte för att jag inte brydde mig om konventioner, utan för att jag var okunnig om dem. I början är allt lätt. Man kan göra lite som man vill. När jag lärde mig mer hände det dock saker. Jag blev säkert bättre på fotografi, men kunskapen om konventionerna hämmade glädjen och allting blev oåterkalleligt svårare. Fotografi har jag i princip lagt på hyllan.

På samma sätt var det med mina studier i sociologi, som jag ju hoppade vidare till för att jag tyckte att sociologi var intressant och för att fotografi hade blivit besvärligt. Hemtentorna och uppsatserna var inte så jobbiga att skriva. De var roliga att författa. Jag behövde inte heller här ta så många konventioner i beaktande. Jag gjorde lite som jag ville. Det var ganska enkelt.

Men så började jag forskarutbildningen. Allt blev återigen oåterkalleligt besvärligt. Det blev omedelbart svårt att skriva och den relativa enkelhet som jag tyckte hade präglat mina tidigare studier var som bortblåst. Länge verkade jag ha helt glömt bort hur man gjorde. Jag medger att tanken på att hoppa vidare for genom mitt huvud fler än en gång.

Jag vet att man egentligen ska säga att det är glädje och kunskapstörst som utgör grunden för ens akademiska förehavanden men mycket av avhandlingsskrivandet har för mig handlat om att skrida till verket trots alla tvetydigheter, motsägelsefulla konventioner och det obehag som alla osäkerheter och krav för med sig. Mycket har handlat om att navigera och hantera det besvärliga för att inte, så att säga, hoppa vidare (även om det nog hoppas lite inne i själva avhandlingen!).

Då kanske man kan tycka att låter som att jag upplevt det som meningslöst att skriva avhandling, men så är inte fallet. Det har varit karaktärsdanande och allt det där. Jag är stolt över att jag gjorde det fast det var jobbigt och inte minst har jag lärt mig mycket om det som ligger bortom hoppandet, hur man kan göra för att stanna kvar. Det finns mening i besväret.

Även om det är ens medmänniskor som påminner en om konventionerna och kraven (och alltså gör det svårt för en!) är det samtidigt just människor som hjälper en att bemästra dem, eller åtminstone hantera och leva med dem. Om man bara hoppar runt är det möjligt att klara saker själv, men bortom hoppandet har jag lärt mig att man inte bör vara ensam. Där klarar jag mig inte själv.

För att få till denna avhandling krävdes det alltså insatser av en massa människor. Inte minst har jag fått assistans av mina barn. Först av min Teodor och sen av min Edvin. Allt annat

bleknar inför deras uppenbarelse! Ni förstår det inte än, men ni har avdramatiserat betydelsen av denna avhandling vilket har varit väldigt skönt. Jag älskar er ofantligt mycket. Ni är min kärlek, stolthet och livsglädje.

Dessutom har jag haft, och har fortfarande, turen att få dela denna kärlek till Teodor och Edvin med dig min kära fru Sofia som på intet sätt undkommit akademins vedermödor. Du har under många års tid har tvingats lyssna på mitt tjat. Du har dock aldrig tröttnat, vilket jag är mycket tacksam för. Även du har påmint mig om avhandlingens ringa betydelse utan att för den sakens skull trivialisera arbetet jag gjort med den. Utan dig hade jag inte orkat. Tack!

Det hade inte heller blivit mycket till artiklar och kappa utan kollegor. Inga alls faktiskt. Innan jag riktar ett särskilt tack till enskilda personer vill jag först passa på att tacka hela institutionen för sociologi och arbetsvetenskap för ett bra kaffemaskins-, korridors- och lunchklimat. Utan spontana samtal om skrivande, publicering, tokiga anekdoter om anonym granskning, litteraturtips, trams och mycket mer hade doktorandtiden varit både sämre och oändligt mycket tråkigare. Inte minst märkte jag värdet av allt detta tydligt när pandemin avbröt oss och jag förpassades till en garderob som fick tjäna som kontor.

Jag vill också tacka alla som kommenterat på mina texter på olika seminarier. Tack Jonas Bertilsson och Christel Backman för era kommentarer på PM-seminariet och för att ni bidrog till att bringa mer ordning i ett *mycket* rörigt skede i avhandlingsarbetet. Tack Caroline Hasselgren och Johan Söderberg för era insatser på mittseminariet. I detta skede sattes kursen mot det som till slut blev av avhandlingen. Er läsning och era kommentarer var viktiga. Tack också till Mattias Wahlström och Anna Storm som på ett föredömligt sätt kommenterade på mitt slutseminarium. Ett särskilt tack vill jag rikta till Mattias som i egenskap av intern granskare engagerade sig extra mycket i avhandlingen i dess slutskede. Avhandlingen utvecklades mycket tack vare alla era respektive insatser.

Tack också till hela STS-gruppen och dess WiP-seminarium vid vilket jag lagt fram texter då och då och alltid fått engagerade kommentarer som resultat. Särskilt tack till Helena Cleeve och Mark Elam som under min slutspurt fick mig att inse att en massa dravel borde tas bort. Kappan blev bättre av det.

Jag vill också rikta ett tack till hela doktorandkollektivet. Tack särskilt till Sarah Philipson Isaac som på ett självuppoffrande, men samtidigt uppmuntrande sätt, engagerat sig både praktiskt och teoretiskt i ofärdiga texter och förbättrat dem.

Tack också för all administrativ hjälp. För en admin-analfabet som jag själv har stödet från en rad personer varit ovärderligt. Tack Pia Jacobsen för svar på *alla* frågor (även långt bortom din arbetsbeskrivning) och också för alla bra diskussioner, tack Anna-Karin Wiberg för all

klarhet som bringats i alla anställningsavtal och sluttider, tack Emma Thelin och Anna Larsson för alla gånger ni har hjälpt mig efter att ha misshandlat Primula, tack Martina Nyström för att du styrde upp EU-projektet. Inte minst vill jag tacka Sandra Schriefer som på ett mycket kompetent vis guidade mig genom avslutet på doktorandtiden. Tack också Anna Peixoto och Cathrin Wasshede för ett gott institutionsledarskap! Särskilt tack till Anna som alltid tagit sig tid att lyssna.

Utan mina två engagerade handledare Göran Sundqvist och Carl Cassegård hade det inte heller blivit mycket till avhandling, den saken är säker. Ni har båda alltid varit tillgängliga, ni har lyssnat och ni har kommenterat och handlett med noggrannhet, engagemang och intresse. Alla doktorander vet att det långt ifrån alltid förhåller sig på detta sätt. Jag har lärt mig mycket av er båda och det har varit ett privilegium att ha er som handledare. Särskilt stort tack till Göran som säkert fick bära en extra börda och frustration under den (ganska långa) del av min doktorandtid då jag var velig, stod och stampade eller var ute på villovägar. Jag hoppas vi får jobba mer tillsammans även i framtiden!

Tack också till alla jag känner som inte varit direkt inblandade i avhandlingen. Det har varit viktigt att glömma den ibland. Tack till min bror Petter Lagerlöf, Hanna Bågler Pros, mamma och pappa för alla middagar och fikor. Tack till hela släkten Mattsson för alla semestrar, besök och umgänge. Tack Anders Nord Hilfing för allt häng och alla icke-instrumentella teoretiska diskussioner som varit grundade i intresse snarare än något annat. Det har varit uppfriskande.

Sist, men inte minst på något vis (tvärtom!), vill jag tacka kompisarna, tillika tidigare doktorandkollegorna (numera doktorer båda två), Jane Pettersson och Caroline. Utan er hade doktorandtiden varit outhärdlig. Ni har varit ett stort stöd och samtidigt visat att man behöver lyssna på trams och att man behöver tramsa själv också. Extra stort tack till Jane. Utan dig hade jag hoppat vidare för länge sen.

Ha det gött!

Hannes Lagerlöf,

Göteborg, april 2023

1 Introduction

Unconditional progress in nuclear waste management?

While various states and enterprises have produced nuclear power for decades, that is, demonstrated the functionality of the nuclear fuel cycle from uranium mining to power production, the waste that is simultaneously produced has been provisionally stored awaiting a safe solution. Still, no country has implemented such a solution.

However, some have gone further than others. For countries struggling to dispose of spent nuclear fuel, and most still do, Sweden is often invoked as a good example of how to go about producing safety in the so-called back end of the nuclear fuel cycle. In this context, Sweden is often referred to as a 'frontrunner' (Elam and Sundqvist 2009; Anshelm and Galis 2011). Sweden does what few have accomplished by showing promising progress towards the realization of 'geological disposal', which, among a vast majority of technical experts, is regarded as *the* technical solution that should be pursued in nuclear waste management (NWM) (NEA 2012; IGD-TP 2016a, 2016b; OECD-NEA 2019). Once the waste is emplaced deep underground, that is, when it has been geologically disposed of, safety is seen by experts as maintained passively with no need for maintenance during the 100,000 years it takes to render the waste harmless.

In 2022, the Swedish national government explained that Sweden would form an exclusive club of states together with Finland as it formally approved the application of the nuclear industry's waste management subsidiary – the Swedish Nuclear Fuel and Waste Management Company (SKB) – to build a final repository for spent nuclear fuel in Forsmark in the municipality of Östhammar (Regeringen 2022). The then Minister of the Environment, Annika Strandhäll, stated in her public announcement that 'more than 40 years of research' had produced a technical solution that was 'well prepared', making Sweden 'world leading' in NWM (Regeringen 2022). Internationally, only Finland is 'ahead', albeit using Swedish disposal technology developed by SKB (Kojo and Oksa 2014). According to the governmental narrative, long gone are the days of conflict over nuclear waste that once was a core trait of Swedish energy policy in the 1970s and early 1980s (Vedung 1979).

While Sweden has claimed for decades to have a 'mature' *technological* system for handling spent nuclear fuel (e.g., SKB 2013a, 2013b), it is not only technological rigour that is represented as a core characteristic of Swedish NWM. To an equal degree, the quality of the *social* arrangements surrounding NWM is said to explain the success and progress. According to this

understanding, it is precisely the *combination* of technologically and socially advantageous qualities that is represented as explaining the accomplishments.

For example, according to the precursor to the Swedish National Council for Nuclear Waste (then KASAM) – which delivers advice and state-of-knowledge reports on issues of NWM to the national government – there is even such a thing as 'a Swedish model' of NWM. While relying on sophisticated technology, the model is simultaneously permeated by democratic governance, and is thus *sociotechnically* robust:

> The Swedish model for consultation and decision-making processes in issues relating to spent fuel, with an extensive exchange of information in a feasibility study phase and with a more formal consultation procedure (according to the 6th chapter in the Environmental Code) at a later stage, is characterized by openness, dialogue and democracy in the municipalities concerned. (SOU, 2004:67, p. 432)

KASAM is hardly the only example of an actor that shares this conception. The success is jointly retold across government entities, industries, and certain areas of the humanities and social sciences. Some scholars are prone to agree with the above statements of KASAM, because Sweden 'draws attention to three key factors conducive to success: an open and lengthy strategy of consultation with the public; widespread pre-existing and reciprocal trust between society and government/industry; and resilient democratic institutions that can channel public opinion, but resist being overwhelmed by it. In Sweden, all three factors combined successfully' (Dawson and Darst 2006, p. 611). Kaiserfeld and Kaijser (2021) have correspondingly claimed that the previously technocratic nature of Swedish NWM in the 1970s and 1980s was subsequently transformed by 'the establishment of a government advisory board [i.e., KASAM] that was able to form an arena for extensive deliberations and reflections on different challenges with broad participation from researchers, implementers, regulators, and later also municipalities and other stakeholders' which in turn 'proved to be a success factor' (p. 1465).

Because nuclear waste is a notoriously controversial issue internationally, the Swedish progress is reassuring to other countries that struggle to implement geological disposal. Sweden has demonstrated the feasibility of transforming perpetual conflict over nuclear power and its waste into cooperation, and dissent into consensus. For other countries that still face public grievances and opposition that hinder the progress of geological disposal, there are thus good reasons for actors in the field to study the Swedish accomplishments more closely.

The accomplishments of Swedish NWM are thus relevant beyond the national context. Importantly, SKB 'exports' – primarily by means of consultation work – its (social) participatory technologies to other countries that still struggle to site geological disposal facilities (Konopásek

et al. 2018; SKB International 2020). Moreover, international and influential NWM organizations such as the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA) spend considerable time producing policy on repository siting strategies at least partly inspired by the Swedish success (e.g., NEA 2007, 2015; IAEA 2020, 2021). Clearly, international NWM has also come to advocate solutions similar to those of the Swedish model of NWM.

The result is transformed NWM governance. While NWM has been critiqued for being a notoriously technocratic field (Blowers and Sundqvist 2010), it has in recent decades incorporated ambitious attempts to refine 'stakeholder engagement' and 'public participation' in order to democratize itself (Sundqvist and Elam 2010; Bergmans et al. 2015). With reference to technologically robust systems for geological disposal, paired with the democratic governance of their implementation, core (European) organizations such as the European Commission's (EC's) Implementing Geological Disposal Technological Platform (IGD-TP) now assert that 'it is time to proceed'. Hence, any 'remaining challenges' – such as the contradiction between equity *within* and *across* generations (Okrent and Pidgeon 2000) – are now essentially represented as overcome, even beyond the Swedish and Nordic contexts.

This progress is complicated by at least two aspects that I will consider. First, NWM has broader implications – that is, consequences beyond the immediate realm it governs – than policy and discourse admit. Despite NWM's technical experts' and other core actors' wishes to refrain from dwelling on the political conflicts that surround energy policy, the legitimacy of both existing nuclear power and nuclear new build arguably hinges on the promises of safety in the 'back end' of the nuclear fuel cycle (Elam et al. 2010). NWM is thus a mainstay of the legitimization of nuclear power, while NWM renounces responsibility for energy-related issues.

Second, the progress implies the assertion that the *dilemmas* of spent nuclear fuel have now been solved. However, the duration of radioactivity inevitably offsets the opportunity to fully 'solve' the waste issue. Some 'challenges' cannot be overcome because NWM entails the inevitable choice between contradictory ethical principles to which there are no 'true' answers. In contemporary NWM policy, perpetual problems of the handling of long-lived nuclear wastes are thus downplayed.

In turn, these two core aspects imply constraints on the range of issues that the institutions of NWM in reality can accommodate. The critical question that should be raised is whether a mode of governance that ignores such broader implications – or at the very least scarcely acknowledges them – really is best described as 'open' and 'democratic'.

The relevance of this question has in recent years increased because political demands for nuclear new build have gained serious traction in the face of climate change, energy shortages,

and the ambition to decrease dependence on fossil fuels, essentially without jeopardizing the 'status quo' (e.g., IPCC 2018; NEA 2022). For nuclear power to be conceived of as a feasible option in this new context, the need to demonstrate safe and democratic NWM correspondingly increases. Essentially, the legitimate progress of NWM implementation is a key aspect for preserving the notion that nuclear power is indeed 'sustainable'.

I will start from the two tensions sketched above, and from the new sociotechnical context in which NWM now finds itself. However, rather than explaining the progress in NWM with reference to a sociotechnically robust NWM system that has overcome longstanding challenges, I will reverse this understanding. I will instead take an interest in why the contemporary modes of governance in NWM remain hailed for their achievements, and how they remain stable, *in spite of* the contradictions and tensions mentioned above.

While the four articles I have compiled in this thesis actualize somewhat divergent problematics and empirical materials, what they together illustrate is that there is good reason to not accept the promises of NWM governance at face value, but to focus on addressing the contradictions and implications they actualize. Together, the studies illustrate *perpetual* problems and concerns implied by the management of nuclear waste that cannot be overcome even by the most sociotechnically robust system.

My main argument will preserve a degree of what I understand to be reasonable scepticism about NWM and the type of democracy it promises; I will propose that spent nuclear fuel and high-level waste constitute 'wicked problems', that is, problems to which there is no one 'silver bullet' solution, only a set of suboptimal options to choose from (Rittel and Webber 1973; Bergmans et al. 2008). In turn, this suggests that the progress gained in one instance typically means regression in another. From this perspective, when NWM progresses, something is simultaneously lost, or indeed sacrificed. Rather than understanding the progress of NWM as best explained by its sociotechnical ability to *solve* problems, I argue that its progress can conversely be explained by NWM's ability to *circumscribe* or at least downplay the inevitable dilemmas and broader implications actualized by the material nature of nuclear waste.

The originality of my project hinges on how these tensions and contradictions in NWM are understood. I will attempt to make two overarching contributions to previous research. First, one contribution is constituted by my attempt to raise a few concerns about the state of research that devotes itself *specifically* to the study of issues of NWM. At the very core, the cause for concern is derived from my observation that NWM has been endowed with a specialized scholarly field that discusses NWM as a phenomenon largely unrelated to other sociotechnical phenomena. In addition to this empirical isolation, however, 'scholarly social scientific research

on … [NWM] has been increasingly articulated within the field of risk analysis' (Solomon et al. 2010, p. 36). As I will discuss in greater detail below, the points of departure of risk analysis are not ideal for my purposes, because there is a tendency to treat what I call problems as *challenges*, insufficiently recognizing the unsolvable nature of nuclear waste problems (see Study II). I will instead hold that an *empirical* demarcation of NWM paired with the points of departure of risk analysis may result in the neglect of valuable theoretical lessons available outside of studies of NWM. This thesis should thus be read as an attempt to broaden research into NWM theoretically and subject the field to a greater range of critical–theoretical scrutiny.

Second, and more importantly, to avoid the limitations of previous NWM research roughly sketched above, and to conceptually clarify the interrelatedness of NWM and its broader implications, I will situate my work in the context of science and technology studies (STS). Mainly, this is because STS considers a much broader range of sociotechnical issues than the empirical field of NWM and risk studies typically do. STS can potentially shed more critical light on NWM. Moreover, STS can potentially bring to the fore the sociotechnical complexity, that is, the issues inevitably associated with NWM that are accommodated in neither general NWM discourse nor most previous empirical research on NWM. I will identify and build on STS and related literature that has already contributed to the study of NWM (e.g., Wynne 1982; Anshelm 2006; Elam and Sundqvist 2011; Soneryd 2016).

However, an important point that I make is that STS – at the overarching level – increasingly has come to elaborate theoretically on *diversity*, *change*, and *volatility*. Since I have identified the objective of this thesis as being to focus on *stability* and *inertia* in NWM, I hold that there is reason to question the degree to which contemporary predominant STS theory has adequate theoretical resources to address such phenomena. While STS has historically been a vital field characterized by theoretical diversity, there is reason to suspect that some of this theoretical breadth has narrowed (Kaltenbrunner et al. 2022). To contribute to the maintenance and/or development of a theoretically diverse STS, I will invoke a range of critical and overarching concepts. Primarily, I will propose that such concepts can be found in 'critical constructivism' (Feenberg 2017a, 2020), and I will elaborate on the prospects of utilizing them to broaden the theoretical repertoire of STS. In doing so, it is my theoretical intention not just to supply empirical insight into issues of NWM by means of STS, but also to elaborate on how issues of NWM have broader implications for the theoretical repertoire of contemporary STS.

Aims and research questions

According to prevailing assertions of NWM, lingering concerns associated with spent nuclear fuel and high-level waste have now been addressed, challenges overcome, and problems rectified, and definitive solutions are now ready to implement. As the IGD-TP (2016a; 2016b) asserts, 'it is time to proceed'. However, if NWM deals with a 'wicked problem' (Rittel and Webber 1973), and I insist that it does, this means that progress *inevitably* comes at a cost that prevailing assertions of unconditional progress say less about, or even ignore. Similarly, because NWM has implications beyond its own institutional confines, which I have also argued that it has, any narrative of progress that leaves out this insight should be subject to critical scrutiny.

My overarching aim is twofold. First, it is to enhance knowledge of the wicked problems in NWM and the broader implications that narratives of progress say little about or leave out completely. Second, it is to provide an understanding of how progress is possible *in spite of* the wicked problems and the broader issues implied by NWM. What is implied by the above aims is, in other words, a focus on exploring what produces stability and certainty concerning an issue as inherently ungovernable as spent nuclear fuel and high-level waste.

By studying the practices and discourses of NWM by means of participant observation and textual analysis, it is my intention to address – at least in a few ways – the problematic sketched above. This project is guided by a set of more specific research questions, stated below:

1) How does NWM, despite its broader function in a system of organizations and technologies, maintain its separation from the other realms in this system? (Thesis frame, studies II and III)
2) How are inherent problems, ambiguities, and broader implications rhetorically and practically handled and addressed in NWM? (studies I–III)
3) Are assertions about NWM progress contested? If so, how? What forms of critique are articulated? By whom? (studies II and III)
4) How do nuclear waste managers address, manage, and respond to (social and technical) critique of – and opposition to – NWM governance? (studies III and IV)

Organization of the Thesis

First, I will present a history of the fields of nuclear power and NWM. This history ends in sketching more precisely the contemporary context in which nuclear technologies should be understood as situated. Second, I describe the nature of previous research. This includes an analysis of the state of studies of NWM, a critique of scholars' previous attempts to blaze paths for future research, and finally a proposal for alternative future research. Third, I account for the prospects of achieving this in the field of STS. Fourth, I introduce and discuss the theoretical resources that I argue can successfully be deployed to deepen our understanding of NWM in its contemporary context, in addition to discussing their potential benefits for future research. Fifth, I disclose the nature of the empirical material I have used for the individual studies. This is followed by an account of the methods that I have relied on as well as a more detailed account of the procedure on which I have relied to analyse the empirical material. This section includes a discussion of the ethical factors I have considered throughout the research process. Sixth, I provide a summary of the compiled papers in English. Seventh, I conclude the main results of the thesis and discuss the implications of my findings for research on NWM and for STS more broadly. Finally, I present a summary in Swedish of the studies compiled in this thesis.

Changing contexts of nuclear technologies

In what follows, I will engage with the history of nuclear power and NWM. This history illustrates the basic observation that neither nuclear power nor NWM is unrelated to its context. Whereas issues of energy policy and waste management are often presented in technologically deterministic ways – that is, as determined by 'inner' forces – this presentation will instead illustrate the interdependencies of technology and the contexts in which they are nurtured. In turn, this implies that the *contemporary* context in which NWM and nuclear technologies find themselves illuminates the need for specific theoretical and conceptual resources that incorporate the ability to address *contemporary* sociotechnical particularities – that is, analysing NWM in contemporary times requires specific resources.

At its very core, nuclear power, at least in the Western context, effectively illustrates the lockstep between capitalism and what Feenberg (2017, p. 2) has called 'the illusion of technology'. Clearly, nuclear power has been a means to advance the narrow goal of *profit*, that is, *the* most central goal of capitalism, while simultaneously being backed up by the idea that nature can be manipulated without 'causal feedback', that is, without the emergence of 'externalities' or unintended consequences. Essentially, the pursuit of profit has historically benefitted from the illusion that we can act upon nature from the outside without experiencing repercussions. While this combination of illusory technology and capitalism is crucial in order to understand nuclear power in its infancy, I will argue that it remains relevant to the present day.

In fact, it is our experiences of causal feedback that have prompted many of our reconfigurations of nuclear power and NWM, but it is simultaneously hubris and the pursuit of profit that time and again have failed to incorporate these experiences to any meaningful degree, producing new illusory technologies and additional ad hoc 'solutions'. Rather than understanding this as 'progress' – as is the case in discourse and in much energy policy – it represents the *repetition* of longstanding ideas about profit and technology as devoid of causal feedback, and as determined by technological forces of progress.

Military applications, fear, optimism, and hope

The era before nuclear power was first introduced was an era of faith in science: 'At the start of the twentieth century many felt that science would lead humanity to an abundance not only of material goods but of brotherhood and wisdom' (Weart 2009, p. 7). Nuclear power is steeped in this optimism that prevailed, not least within the natural sciences. This optimism triumphed regardless of whether one was in, for example, the Soviet Union or the United States; nuclear power held the promise to realize a range of sometimes competing and incommensurable ideals. Alongside one another, a variety of states worked on their respective nuclear power programmes. In 1953, the Soviet Union was the first state to connect a reactor to the power grid, but England followed soon after, as did many other countries. Sweden was no exception in this context, and in 1963 it launched its first nuclear power plant, the Ågesta Power Plant.

The origins of nuclear power, however, are military. Nuclear reactors would power submarines and aircraft carriers, giving an advantage over the enemy by reducing refuelling demands. It was only after military applications that the civilian use of nuclear power gained traction as well. The splitting of the atom was eventually seen not just as a means to wage war, but also as a means to improve society.

In the 1950s when fission had gone from idea to a functioning energy-producing technology, nuclear power was essentially a subject for in-house scientific debate among scientific elites. Still, public fear of – and concern about – nuclear technologies and radiation was not insignificant after the American nuclear assault on the Japanese cities of Hiroshima and Nagasaki in 1945. These events had effectively shown the destructive potential of splitting the atom. Despite being a question for elites, there was still a need to display the *benefits* of various nuclear technologies (i.e., nuclear weapons and nuclear power) to citizens, for example, via famous newsreels that pictured bombastic technological infrastructure, and impressive scientific achievements to overcome the public fear of nuclear technologies that coexisted with the optimism (Pfister 2015). However, there were also infomercial productions that showed how to deal with the dangers of the atomic bomb. The most famous is perhaps the 'Duck and Cover' safety campaign that educated school children about how to behave in the event of a (Soviet) nuclear attack on the United States.

In the face of the 'nuclear arms race' in which primarily the United States and the Soviet Union increasingly and in parallel increased their nuclear weapon arsenal, public concern about nuclear technologies was not limited to just military applications of fission. This prompted Dwight D. Eisenhower's famous distinction at the UN General Assembly in 1953 between

'atoms for peace' and the proliferation of nuclear weapons, that is, 'atoms for war'. Essentially, civilian nuclear power was understood as in need of a new set of imageries that did not involve fear and destruction; it needed to rid itself of its military associations.

Clearly, the optimism was at least in part based on a lack of knowledge of the inherent properties of the material that was produced when producing power by means of fission. In fact, from the optimistic imageries of atoms for peace and the ideas that preceded it, it is not hard to understand that spent nuclear fuel was considered rather unproblematic. In the early days of nuclear power, technological optimism held that spent fuel should be considered an *asset* for future societies and more advanced technologies to exploit (e.g., Anshelm 2006). What was expected were enhanced methods that could extract the energy potential remaining within the uranium rods after power operations and electricity production in the first generation of reactors.

The history of nuclear power and NWM shows that context matters. Societal demands, expectations, prevailing ideas, and so on heavily condition the use of fission. Although conceived in times of optimism, nuclear power has also been invoked as a cure, or 'necessary evil', in times of crisis. Most notably, in response to the oil crises of the 1970s, nuclear power was used as a means to circumvent the problems the crises entailed. As the seemingly endless spiral of growth and increased material prosperity was broken, fission was introduced as a source of energy that did not rely on the extraction of oil from fields in remote, conflict-ridden places. The production of domestic energy would effectively decrease the reliance on the stability of foreign geopolitics and restart production of goods and commodities, in turn securing jobs and continued prosperity. A result of this endeavour was the construction of many nuclear power reactors worldwide. This was also the case in Sweden, with its quite rapid increase in the use of energy produced by fission, which meant that while oil use decreased, total energy consumption increased.

The ambition to expand nuclear power in the wake of the oil crises of the 1970s was, however, not uncontroversial. While the oil crisis in 1973 and the 'second oil shock' in 1979 revealed the limitations of previously taken-for-granted economic progress and exposed the vulnerability of an economy that relied on fossil fuels, the technology of nuclear power simultaneously experienced near devastating blows to its credibility. The Three Mile Island accident at the Harrisburg Nuclear Power Plant, USA, in 1979 indeed resulted in a core meltdown, although radionuclides did not spread widely and were largely contained. This was the 'Titanic' event of nuclear power. The accident testified to the limitations of the experts' view that the technology was safe. Broad swathes of the public realized how close to disaster they had

come, increasing the pressure on technical expertise and resulting in a general decline in the trust in fission.

Nuclear accidents testify to the significance of the broad organization of social movements in the face of disasters. Whereas the organization of protests based on various types of collective grievances is a significant aspect of many political conflicts, nuclear accidents present a *particular* type of problematics recognized by broad parts of the general population. Nuclear accidents, such as that in Harrisburg, have illustrated the *rapid* growth and development of organized resistance that can occur when nuclear technology malfunctions. While the presence of grievances is seldom enough for broad mobilization, the suddenness and potential gravity of nuclear reactor failure have demonstrated that the public organizational response to nuclear accidents has few, if any, equivalents (Walsh 1981). Nuclear technologies have indeed been particularly – and collectively – upsetting to a range of social groups that otherwise scarcely interact, but that through protests share a common goal.

In 1986, however, fear of total nuclear disaster was an undeniable fact. Unlike in the Harrisburg accident, at the Chernobyl power plant in Ukraine, the reactor core could not be enclosed upon meltdown. The consequences of the accident were vast and far-reaching, and importantly, both the Western and Soviet blocs now had their own respective experiences of nuclear power failure: the Harrisburg accident made it somewhat difficult for the West to blame the Chernobyl catastrophe solely on Soviet technological inferiority.

The aftermath of these nuclear failures shows the importance of recognizing the lockstep between capitalism and the illusion of technology. Rather than completely abandoning nuclear power in the face of the accidents, there was an effort to 'tame' it (Bösch 2017). For instance, the West German response was to take command of the situation 'by increasing safety measures and abandoning plans for new nuclear power stations, and politically, with a more critical appraisal of nuclear energy and with semantics that encouraged a long-term withdrawal from nuclear power' (Bösch 2017, p. 94). It is safe to say that many other countries also implemented similar responses. The nuclear crises intensified the scientific safety assurances, but nuclear power continued to play an important role in the energy supply, albeit not as central as before.

However, it is important to note that the aftermath of the Chernobyl accident allowed for more nuclear flexibility than did the Harrisburg accident. Once again, this has to do with the access to (cheap) oil. In 1979, oil prices were high in the face of the 'second oil shock', 'but it was easier to turn away from nuclear energy after Chernobyl because oil prices were now plummeting and new energy reserves were emerging' (Bösch 2017, p. 95). In a time before the climate crisis had made its way into the broader public energy discourse, the situation in the mid and late

1980s enabled states' and other actors' consumption of *both* fossil fuels and nuclear power. Controversies over nuclear power and the dent in the public trust in expertise enabled a return to increased fossil fuel consumption and less emphasis on fission-produced energy.

Nuclear power and conflict

The transition from energy production that relied on foreign conditions and geopolitics, to domestic energy production through nuclear power was nevertheless far from smooth. Public outrage at the potentially devastating consequences of nuclear power plant failure and the resulting opposition to nuclear power were fierce internationally, as well as in Sweden (Anshelm 2000, 2006). The question of whether to expand already-initiated nuclear operations was one of the most controversial questions on the political agenda in the 1970s and 1980s.

Recent nuclear accidents had confirmed public concerns and given social movements ammunition with which to criticize the technological confidence of technical experts. The 'waste/asset' divide is important in this context. It had become increasingly clear that the early-1900s optimism about future technologies was not going to be realized, as the technological promises could not be fulfilled within a foreseeable future. Put differently, causal feedback informed us that the optimism had been misguided: technical action had consequences and the spent nuclear fuel would have to be handled. Causal feedback turned the asset to waste, and the field of nuclear energy thus faced new problems (Anshelm 2006). The continuation of nuclear power now relied on pro-nuclear interests to demonstrate the technological feasibility of safely *managing* the waste, not utilizing it.

The birth of Swedish NWM serves as a good case illustrating the new problems that nuclear power faced. As an example of the impact of the nuclear issue, the centre–right coalition government elected in 1976 was dissolved in 1978 because of internal schisms directly related to the increase in nuclear power use. Before the governmental breakdown, nuclear-sceptical political leaders sought to limit nuclear power by legislative means. By 1977, the now famous Nuclear Power Stipulation Act (SFS 1977:140), which postulated that nuclear power plants could be commissioned only if the operator could provide an 'absolutely safe' technology for the final disposal of the nuclear waste, came into force. The controversial Act, developed by the nuclear-critical liberal agrarian Centre Party, which initially intended to put an end to any extensions of the Swedish nuclear power programme, nevertheless had an effect opposite to what was intended. Providing 'absolute safety' was essentially seen as unachievable, and thus would ensure

that no more reactors were put into service. Technical infeasibility would secure the critics' political victory.

However, the Act was eventually reinterpreted by the Centre Party's coalition partners, primarily by the conservative Moderate Party, which agreed that the demands indeed were stringent, but not unattainable. In 1976, the Parliamentary Committee of Industry stated that the requirements were stringent, but that 'a draconian application of the safety demands is not intended' (Näringsutskottet 1976). Contrary to its original purpose, the Act came to represent the *safety awareness* of Swedish nuclear waste governance. Surely, the 'absolute safety' of NWM, guaranteed by state-of-the-art technology, would leave even opponents content with the continuation of nuclear operations. Following this 'backfire' of the 1977 Act, leaders started seeking technical answers to the ambitious safety demands as the nuclear power issue was reframed from a political issue into a technical safety issue.

A technical solution, it was envisioned, would put an end to political conflict, take the edge off the nuclear critics' risk arguments, and satisfy the strict legislative demands. Prosperity would thereby be ensured but not at the expense of personal and environmental safety. The responsibility fell on the nuclear industry to provide the 'absolutely safe' technology, which was now understood as a feasible task. These chains of events – and the founding of the nuclear industry subsidiary SKB – the Swedish Fuel and Waste Management Company – eventually led to the birth of the Kärnbränslesäkerhet (KBS, i.e., nuclear fuel safety) concept. By emplacing the spent nuclear fuel in metal canisters deep in bedrock, SKB argued it could achieve safety 'passively', that is, establish safety a priori, and indeed for eternity or at least one million years. Passive safety is thus the idea that once spent fuel has been emplaced, there should be no need to uphold safety *actively* for 100,000 years until the waste is rendered harmless. Safety is produced a priori by means of scientific calculation and technological excellence.

The introduction of KBS was successful in the sense that it took the edge off anti-nuclear actors' criticism. Whereas the conception of Sweden as an open democracy sensitive to public demands is generally the view that permeates the language of the Swedish model of NWM, the power of the state has often triumphed over social movements' attempts to redefine policy. For example, compared with Germany and other countries where anti-nuclear movements have been more successful, "where political capacities were stronger, as in Sweden and France, nuclear policy was shielded from most of the attacks on its implementation" (Kitschelt 1986, p. 84). However, even in Sweden, political leaders still acknowledged that the nuclear power issue was controversial enough to warrant a national referendum, which is a rather unusual solution in Swedish politics. In 1980, shortly after the Three Mile Island accident, the referendum

commenced, offering three 'plans' voters could choose from: 'there would be three alternatives, two "yes" (plans I and 2) and one "no" (plan 3)' (Sundqvist 2002, p. 93). However, for 'tactical reasons the pronuclear alternative was split into two different but very similar alternatives' (Sundqvist 2002, p. 93). This meant that while plans 1 and 2 were presented as distinct alternatives, they were both essentially pro-nuclear. The results of the referendum were interpreted as clear. Plans 1 and 2 (the 'yes' alternatives) received 58 per cent of the votes, whereas plan 3 (the 'no' alternative) received 38.7 per cent. This outcome meant that nuclear reactors could finally be fuelled, albeit with the promise to decommission nuclear power by the year 2010 (a promise that we now know has not been fulfilled). The pro-nuclear actors had essentially won the 'battle' and nuclear power was saved.

For many engaged in social movements opposing nuclear power, the introduction of KBS and the results of the referendum represented a definitive defeat. The hope to put a stop to nuclear power virtually vanished as the accumulation of waste guaranteed essentially eternal perpetuation of environmental risk. This was interpreted by many as a situation in which alternative energy futures would *never* be fully realized. Consequently, today the social movements dedicated to the abolition of nuclear power are a fraction of their former size.

Birth of a technical paradigm: From political conflict to technological consensus

The above events had consequences for the bureaucracy surrounding nuclear power and waste management. While the waste issue had been treated as an integral part of the nuclear power debate in the 1970s and early 1980s, subsequent decades came to be characterized by a quite radical divide between issues of *energy* and issues of *waste*. Despite their interrelatedness, the two issues were to be kept separate.

After the pro-nuclear victory and the proclamation of the attainability of 'absolute safety', the industry proceeded with its plans. However, the industry was to be held accountable to public authorities specializing in issues of nuclear safety. This was the birth of an organization that conducts its business beyond conflict-laden energy policy (which is out in the open), in the more closed world of authority auditing.

The audit procedure according to the Nuclear Technology Act (SFS 1984:3) – the legislation replacing the Stipulation Act in 1984 and imposing slightly more modest safety requirements – is characterized by a certain predictability. Organized around a cyclical system, the industry presents its research and development every three years in reports known as Research,

Development, and Demonstration (FUD) reports (e.g., SKB 2007). These are audited by the Swedish Radiation Safety Authority (SSM).

What the audit system revolves around is the *technical feasibility* of KBS, that is, the geological disposal system developed by the Swedish nuclear industry subsidiary SKB. Now in its third version, KBS-3 works in the following way. It consists of three barriers: the first is a copper canister, the second is bentonite clay, and the third is crystalline bedrock. The spent nuclear fuel is emplaced in the canister, which is subsequently welded shut. The canister is emplaced approximately 500 meters underground in bedrock in boreholes, surrounded by bentonite clay buffer that swells in contact with water (SKB 2007, 2013). For 100,000 years, the waste then slowly decays until it reaches harmless levels of radioactivity. This process is at its core 'passive', which in essence means that no surveillance or supportive measures need to be taken to achieve 'long-term safety'. Hence, we can 'walk away' from the repository and leave it be once it has been enclosed.

According to the provisions of the Swedish audit system, the nuclear industry has continuously and rather independently developed the KBS-3 concept, ensuring that it meets the high governmental standards, but has simultaneously been shielded from potentially conflictual energy policy debate. Simultaneously, however, the *promise* of the disposal technology has legitimized further exploitation of nuclear operations for decades (Elam et al. 2010). The high safety ambitions have also been successful insofar as they have rendered the nuclear power issue politically uncontroversial: the technological promise has contributed to making political critique redundant in the face of the technological paradigm, which has succeeded in the conflicts of the past. Albeit with some technological divergences, 'geological disposal' is now the preferred technology elsewhere as well. There is technological consensus that safety can be achieved by geological disposal, which we examine in Study 1 (Lagerlöf et al. 2022).

The nuclear industry has progressed in its efforts to consolidate its technological waste management solutions. Part of this progression can be attributed to NWM's ability to enrol *science*, not least to establish trust and confidence in the technological solutions. While the nuclear industry clearly has an economic stake in realizing geological disposal, and in putting an end to the enduring – and costly – waste management challenge, and while it conducts much of its research beyond the realm of academia and the public, it has still rhetorically employed a seemingly apolitical scientific rhetoric that makes recurrent references to *objectivity* and *impartiality*, thus detaching NWM from the destructive 'subjective' political conflict surrounding nuclear power. This nurtures a focus on scientific and technological consensus instead of on political

conflict. Much of the success of NWM in demonstrating safety can be attributed its ability to communicate the achievement of technological consensus among its key actors.

William D. Magwood, Director-General of the NEA, neatly demonstrated this by stating that 'international co-operation can help achieve national solutions through the exchange of information and co-ordination of policies, and by developing a consensus on international standards' (NEA 2019). In such a context, where 'the political' has been technologically reframed, contemplating and speaking of controversial subjects such as ethics, risk assessment, and uncertainties are largely understood as requiring *technical* expert knowledge. In sum, the strategy to address criticism of nuclear power by means of science and technology has been largely successful from the viewpoint of pro-nuclear actors.

Technical critique and decades of relative quiescence

The technification of NWM and the decline of social movements are interrelated. Yet, there is still opposition to the repository plans. An important matter to note, however, is that following the legal and technical reframing of the nuclear power issue in the 1970s, a new form of critique emerged, at least in Sweden. It was scientific and technical in nature and has proven to be enduring. The declining political critique following the new techno–legal reframing of the nuclear waste issue was replaced with a techno–scientifically oriented critique that largely dealt with technical details specified in the KBS-3 project (Anshelm 2006).

It is safe to say that the emergence of this technical critique has social causes, as the radical divide between energy policy and NWM has shrunk the space within which one can voice concern. While a geological controversy, that is, scientific disagreements over the solidity and permeability of various types of bedrock, was active in the 1970s and 1980s, an additional enduring example of technical critique in Sweden is the controversy over the canister material choice. More specifically, this controversy concerned the corrodibility of the material, a matter elaborated on in Study II. For decades, industry and corrosion scientists have disagreed about the corrodibility of copper in oxygen-free water (e.g., Hultquist 1986), and the controversy has been granted space because of the manner in which energy issues are organized: technical issues thrive in this context at the expense of political reflection.

From a sociological perspective, then, it is perhaps unsurprising that the technical debate has prevailed and that the battle between conflicting interests has been waged by means of scientific calculation. The copper controversy testifies to this, as virtually all engaged organizations – whether pro or anti nuclear – have engaged wholeheartedly in the corrosion debate. While SKB

has uninterruptedly claimed that copper will last for at the very least 100,000 years (SKB 2013a, 2013b) until the nuclear waste has decayed and become harmless, researchers from the Royal Institute of Technology (KTH) in Stockholm, Sweden, have insisted that the copper will corrode quite rapidly, starting just 100 years after emplacement in the bedrock (Orring 2017). In many ways, the copper controversy has been represented as one of few (perhaps the only) obstacles prohibiting the final disposal of nuclear waste, whereas 'the political' and 'the economic' are often completely absent. As such, the entire project of nuclear power has indirectly hinged on the corrosion properties of copper. I describe the centrality of technical critique in Swedish NWM in Study II.

Technical disagreements notwithstanding, nuclear power and NWM have since the conflictual decades of the 1970s and 1980s (Anshelm 2000, 2006) long been characterized by decreasing overt social conflict. The 1990s and 2000s brought with them fewer public protests, although there were examples of a few local conflicts. As the Swedish example effectively illustrates, previously deeply engaged social movements lost virtually all momentum after the national referendum in 1980, which resulted in the somewhat whimsical outcomes of, on one hand, perpetuating nuclear power and, on the other, promising its dismantling by 2010 (e.g., Sundqvist 2002, p. 92). However, there is one form of conflict that has proven to be enduring and that is waged beyond the national political arena. In what follows, I describe this conflict in more detail.

Mature technology, nowhere to site

The largely successful strategy notwithstanding, the technical response to political conflict was still insufficient if there was no place to *site* the safe NWM technologies. Even though there are risks associated with nuclear power operations – such as core meltdowns and the subsequent dissemination of radionuclides – the back end can be understood as the enduring 'Achilles heel' of the nuclear industry (Blowers and Sundqvist 2010). Many countries that have expanded nuclear power have been deeply unsuccessful at implementing solutions to the waste problem.

Typically, this inability has had social reasons: *local* concerned publics have dismissed the nuclear industry's plans for building repositories in their communities. In the 1980s and early 1990s, siting actors foresaw choosing repository sites based on solely technical criteria. Still, as became evident later, it was local opposition that posed the greatest obstacle. Many examples testify to this, and the coercive strategy of appearing uninvited in municipalities to start site investigations has been largely unsuccessful (Sundqvist 2002). To cite a few Western examples,

this has also been the case in Gorleben, Germany (Hocke and Renn 2009), Yucca Mountain, USA (Solomon 2009), Bure, France (Barthe and Mays 2001; Barthe 2009), and several sites off the Cumbrian Coast, Great Britain (e.g., Blowers 2010, 2016). The tenacity of local opposition eventually prompted siting actors to account for their intentions in formal forums, such as municipal councils. In the end, it became obvious that there can be no circumventing of publics in siting endeavours.

This realization has given birth to new strategies that go beyond strictly technical projects previously assessed as sufficient for addressing public criticism of nuclear power and its waste. Siting actors were in many cases forced to withdraw, rethink, and regroup. The 'participatory turn' in NWM during the 1990s marks new strategies that sought to resolve conflict by the *inclusion* of so-called concerned stakeholders (Sundqvist and Elam 2010; Bergmans et al. 2015). Typically, implementers developed a range of 'social technologies' to bridge the gap between technological concepts and (local) public opinion.

In Sweden, the most prominent example of this turn is the so-called feasibility studies launched in 1992. These studies were a strategy based on 'voluntarism': municipalities should nominate *themselves* as interested in becoming nuclear waste hosts (Sundqvist 2002). In Sweden, the industry invited all Swedish municipalities. A handful expressed interest. Politicians in the two somewhat geographically remote municipalities of Storuman and Malå, situated in northern Sweden far from nuclear power plants, responded first, but the public voted 'no' to site investigations in local referendums instigated by protesters.

Nyköping, Älvkarleby, Hultsfred, Tierp, Östhammar, and Oskarshamn were the only remaining volunteers after the early withdrawals, and the industry was finally allowed to investigate these sites as there was little or no local resistance there. While SKB had, upon its launching of the coercive site investigations, stated that its goal was to find the 'best' bedrock in Sweden, that is, to site a repository based on strictly technical criteria, it subsequently settled for 'good enough' bedrock. As we now have learned, 'good enough' bedrock has now been found in the municipalities of Östhammar and Oskarshamn, both of which already host nuclear power plants (the Forsmark and Oskarshman power plants). Additionally, Östhammar has already hosted a repository for medium-level radioactive waste since 1988, and Oskarshamn hosts the national interim spent nuclear fuel storage facility. These previous experiences, and various forms of economic dependence on the continuation of nuclear power operations and waste management, are among the reasons why the 'voluntarism' approach has rendered concrete host sites, a matter explored in Study III. Sweden and Finland (Aufferman et al. 2015) thus constitute

the exceptions that prove the rule, being the only two countries worldwide that can be said to have successfully found sites to implement their NWM technological solutions.

NWM is, however, an activity that will last decades or even centuries. Focusing on gaining 'public trust' and 'public confidence' has been as important for implementers as has solving the strictly technical challenges (Lidskog and Andersson 2002). IAEA Deputy Director General Mikhail Chudakov expressed this view in an IAEA news article, stating that 'transparent and fact-based communication with the society at large not only contributes to the introduction and acceptance of nuclear power programmes, but also enhances safety and security' (IAEA 2017). While Chudakov spoke specifically of nuclear power, this rationale also applies to NWM. Many of the key actors have developed programmes to enhance public communications to 'build trust' and 'produce confidence' in technical expertise and technological solutions in NWM. For instance, IAEA (2020) has developed 'Trust as a Communication Principle', stressing that controversies arising from questions about nuclear power and NWM can be partly remedied by the diffusion of facts and science-based arguments. On its website, IAEA urges implementers to 'set clear expectations. Communication may invite controversy. It involves managing risk associated with the high emotions some people have towards the issues related to nuclear power generation, decommissioning or waste disposal' (IAEA 2020. Important features of the social strategies of NWM are therefore to spread knowledge to the public, because 'there is a clear correlation between knowledge and support. Large parts of the public are still unaware of (or choose not to believe) the potential benefit of nuclear energy to reduce the emissions of climate change related carbon dioxide' (OECD-NEA 2010, p. 7).

While the lingering technocracy in NWM has received much attention from social scientists, it is simultaneously the case that participatory technologies have evolved since the participatory turn. To be sure, the 'information campaigns' instigated by implementers to teach the public about technical issues deserve scrutiny. Nonetheless, implementers have listened to social scientists. As we will see, in this thesis I will identify new steps that implementers have taken to facilitate 'successful' implementation. I elaborate on this in studies II and IV.

In short, however, implementers have deepened their commitment to participation. In this context, Sweden is once again the 'forerunner'. The Swedish experience has been deemed the ideal, and there have been attempts to 'export' Swedish participatory technologies (Konopásek et al. 2018). Importantly, we have learned that 'evidence from the Swedish and Finnish geological repository siting programmes for high-level waste – with an emphasis on public participation – suggests that using a science-focused-based program is deficient' (Sanders and Sanders, 2021, p. 6). What Sweden and Finland demonstrate is rather that *consent* – and not just scientific

knowledge – is crucial for NWM: 'numerous countries have begun to focus on "consent-science-based" processes for the siting of a deep geological repository' (Sanders and Sanders, 2021, p. 6). This development suggests a shift from *teaching* publics scientific 'truth', to seeking to *transform* their voiced interests and even 'high emotions' regarding NWM issues. As we will see, this entails efforts that go beyond mere attempts at 'speaking truth to publics', because implementers now consider 'old' information campaigns to be insufficient for building consent. In addition to 'economic incentives', one has to make publics actually *want* the repositories. In this thesis, studies III and IV elaborate on two different ways implementers have sought to do so.

As I have sought to make clear, siting attempts are ongoing and typically unsuccessful projects worldwide, but Sweden has 'completed' this task since the national government in 2022 approved an SKB request to construct a repository in Östhammar (Regeringen 2022) after being prompted by local politicians in the municipality to do so (SVT 2021). As it now seems, the siting chapter in Sweden is 'complete'. In what follows, I elaborate on the conflicts that have re-emerged in what I call 'the contemporary context' and attempt to demonstrate what is at stake in NWM and energy policy at the time of writing.

The contemporary context: New-old problems, new-old ideas

Alongside the technical consensus culture that so pervasively seeks to avoid contention and keep NWM out of the energy policy debate (see Study I), the nuclear power controversy is simultaneously on the rise. The broad relative quiescence surrounding nuclear power that has reigned for decades has been replaced with the rebirth of a significant atomic power optimism in conflicts over energy policy. Nuclear power has once again secured a central role in energy policy, at centre stage in both parliamentary politics and extra-parliamentary debate (Knutson 2021).

It is not, however, primarily the long-quiescent concerns about nuclear power and its waste that now have simply been resurrected. The context in which nuclear power now finds itself is to some extent new. Public support for nuclear new build is at an all-time high (Lindström 2021), although this support is perhaps contradicted by a possible decrease in public support for existing power plants (Levin 2021). At the time of writing, we are learning daily about the increasing public support for nuclear energy.

Regardless of these contemporary twists and turns, nuclear power now appears attractive to a broader range of states, enterprises, and publics largely because of its alleged potential to 'combat climate change'. Sometimes referred to as 'Climate First', a fairly substantial set of actors

and organizations now promotes nuclear power as *the* fundamental 'climate mitigation tool' (Katz-Rosene 2021). These actors, who often present themselves as part of the 'environmental movement', represent nuclear power as desirable due to its presumed capacity to provide clean energy without imposing any limitations on energy consumption (Ekomodernisterna 2022).

In these contexts, nuclear power is typically described in quite optimistic language as having a core function in 'green progress'; there is great faith that linear scientific and technological progress will remedy any lingering problems of today. Fourth-generation nuclear power and so-called small modular reactors are typically the reference points for actors who foresee the re-transformation of 'waste' into an 'asset': spent nuclear fuel is once again viewed with optimism stemming from the potential to capitalize on as yet nonexistent technologies, that is, more advanced power plants. Hence, nuclear power now typically features in various calculations of energy mixes and energy scenarios intended to yield low emissions of greenhouse gases, while not sacrificing or even increasing energy production (e.g., IPCC 2018, NEA 2022).

While nuclear power was on the decline after the Fukushima accident in 2011, we are now witnessing a significant turn in the other direction. Nuclear power has found a place in the European Union's (EU) taxonomy of sustainable technologies that qualify as 'green' (BBC 2022). Although far from free of the criticism that the new emphasis on nuclear power is a form of 'greenwashing' (BBC 2022), generally speaking, the nuclear power discourse is more deterministic than it once was.

Technological determinism, that is, the idea that science and technology advance linearly 'outside' of social interests, now has made a notable comeback. Whereas historical conflicts over nuclear risk once touched on issues of ethics, environmental justice, and the realization of political ideals, that is, broader issues with technological implications (Sundqvist 2002), it is not these aspects *per se* that primarily characterize present-day struggles. Nuclear power is now better understood as the *means* by which various policy and energy futures are supported and advanced – or indeed rejected – in the wake of global warming and ongoing ecological disaster. As the Swedish Social Democrats now put it, 'when it comes to solving Sweden's need for energy, there are to us Social Democrats no sacred cows' (Socialdemokraterna 2022).

Technological determinism has been exacerbated by skyrocketing energy prices, which have also sparked interest in nuclear power. While there are many reasons for the increasing prices of electric energy, Russia's recent downscaling (and cancellation) of its exports of fossil gas to Europe – in response to European economic sanctions on Russia in the face of the war in Ukraine – has strengthened the view that states once again need to secure their domestic energy production. Germany's decision to dismantle its nuclear reactors after the Fukushima accident in

2011 and Sweden's dismantling of several of its reactors in recent years are decisions now met with both anger and disbelief. Anti-nuclear positions are often met with scepticism and there is evidently little interest in discussing the nature and validity of our 'need' for energy. This need is essentially naturalized and energy systems – grid systems – sized for big flows of energy do not always allow for down-scaling. A sizable flow of energy has been made crucial to – and built into the logic of – contemporary capitalist economies and our 'Western way of life'. Accumulation of capital relies on big energy (Hornborg 2019).

There are more examples to substantiate the claim that nuclear power is increasingly represented as inevitable, that is, 'determined'. Some groups that one previously would have expected to be anti nuclear have now changed positions. For instance, there is increasing fragmentation of both the parliamentary and non-parliamentary left (e.g., Heimersson 2020; Philipsson 2021). Although rarely enthusiastic about nuclear power, many of those who have changed their opinion stress that nuclear power is now unavoidable given the impending threat posed by CO_2 emissions. Some Marxists argue that, given the urgency of the impending threat of the mass destruction of nature caused by capitalism, preoccupation with criticizing or acting to oppose nuclear power is detrimental, as it saps the attention and potential of the left to organize actions to address the acute need to mitigate greenhouse gas emissions. Additionally, Marxists may believe in the potential of nuclear power to liberate the global proletariat (Walters 2013).

Although guided by contradictory social interests, more right-wing accounts typically also resort to determinism and instrumentalism as they make it clear that nuclear power is inevitable given the alternatives, which are typically represented in terms of economic disaster and market freefall (Dilot 2015; Dilot et al. 2016). This is certainly true in the Swedish case, as centre–right parties (including the Social Democrats) now make the continuation – and indeed expansion – of nuclear power into a core political issue while simultaneously claiming that this project is essentially inevitable and thus 'unideological' (e.g., Moderaterna 2022). Notably, the campaign preceding the September 2022 national elections in Sweden spent considerable time promoting nuclear power as the answer to both climate crisis *and* economic decline.

Of course, not all accounts are supportive of nuclear power, although the critique is typically not far reaching, being primarily economic–technical in nature. One clear tendency is a form of critique that is coupled with optimism about 'alternative' energy sources such as solar and wind power. What is significant about these accounts is not their systemic critique or disapproval of nuclear risk based on various ethical and political considerations, but that they echo the view that green technologies have the ability to perpetuate the status quo, that is, that they can *match the efficacy* of fission energy, or even that nuclear power is insufficiently 'competitive'

(Naturskyddsföreningen 2021). One of the stronger arguments for anti-nuclear actors, however, is that nuclear power stations cannot be constructed in the blink of an eye. The Finnish construction of the Olkiluoto 3 station testifies to the risk of both budget overruns and construction delays. From this perspective, new nuclear power stations and improved power grids are proposed solutions that are decades away, while we needed to act yesterday to address the climate crisis. Moreover, uranium mining and transport as well as other tasks required to fuel nuclear power stations are not insignificant sources of pollution and CO_2 emissions.

That the nuclear industry and other powerful actors are now on the verge of realizing their long-standing plans to dispose of nuclear waste deep in bedrock (e.g., SKB 2011a, 2011b, 2011c) – so-called geological disposal – counters the prospects for introspection in the field and bolsters the perception that critique is now redundant, obsolete, or possibly even destructive. In the contemporary atomic power discourse, the issue of nuclear waste is hardly of any real concern to pro-nuclear actors and has gained little if any airtime in recent political debates. If NWM is invoked in debate, it is typically to demonstrate that the Swedish model of NWM is superior or at the very least sufficient, and that the waste issue has now finally been resolved. Progress has rendered concern obsolete.

Nuclear power's waste issues appear trivial in this new context but, as the studies compiled in this thesis show, are not insignificant. The energy-by-fission optimism still indirectly feeds on the alleged sociotechnical advances made in the back end of the nuclear fuel cycle. Chronic technocratic problems of NWM (Blowers and Sundqvist 2010) have been represented as largely resolved by 'changing system culture' (Kaiserfeld and Kaijser 2021) and by advances in public participation exercises where citizens and industry are now said to participate on equal terms (e.g., NEA 2015). The legitimacy of nuclear power is thus inflated not just by 'inevitability', but also by the promise of safe and democratic NWM (Elam et al. 2010).

In other words, a range of contemporary deterministic sociotechnical tendencies would discourage the project of addressing the array of inevitable sociotechnical problematics implied by both nuclear power and NWM. In sum, rather than presenting anything essentially new, the contemporary context represents a 'new' *set* of old ideas, hopes, and expectations. Yet, I hold that these tendencies make it even more important to address what is left out of public discourse, to explicate the problems of nuclear power and the limitations of NWM. In this field, public participation technologies have evolved that are represented as democratic, but of which we know very little. How are the more advanced forms of consent-building conducted? If technological determinism is mistaken, what is a better way of approaching nuclear power and NWM?

The studies compiled in this thesis should be understood as a sociological response to these societal tendencies and as addressing the research questions stated above; the studies seek to clarify at least some of the aspects of how NWM has evolved and adapted to critique. I will propose that, first, the separation between the two interdependent projects of nuclear power and NWM needs contextualization. Second, I will propose an improved way of establishing the degree to which 'immutability' and 'change' can be invoked in the new discussions of energy policy. Rather than understanding nuclear power as either 'inevitable' or 'uncompetitive', it appears more accurate and productive to acknowledge that the sociotechnical pros and cons of nuclear power are relative to the political and ethical *values* we hold. It is not difficult to understand positions that are anti or pro nuclear. What is more unfortunate, however, is the unimaginativeness associated with prevailing nuclear power optimism *and* criticism, and the neglect of the interests that inflate pro-nuclear positions and mask them as 'determined' by naturalized economic forces.

Finally, I will argue that NWM deserves much more attention in the energy debate; referring to a democratic Swedish model of NWM simply will not do given the deficiencies of the model that I will demonstrate. Rather than understanding the nuclear waste issue as overcome by means of social, technical, and scientific progress, the studies compiled in this thesis testify to the *chronic* pathologies produced by nuclear power, technological optimism, determinism, and an endless and naturalized 'need' for increasing amounts of energy.

3 Previous research on nuclear waste management

Introduction

In what follows, I will explore previous research on NWM. First, I will present an overview of the field and sketch some general empirical, theoretical, and temporal tendencies. Second, I will account for recent recommendations for future research that have surfaced in the field as a point of departure for discussing research paths forward. Third, I will critically discuss these recommendations. This discussion situates the contents of this thesis within the broader body of literature about NWM based on an alternative conceptualization of how to understand previous research. Fourth, my core concern will be to build on STS-inspired literature that has engaged with issues of NWM, but I will also seek to theoretically elevate the discussion to facilitate some core concerns of STS, beyond the concerns of existing NWM research. In so doing, I hope to contribute not just to studies of NWM, but also to the advance of the STS field more broadly.

One empirical field, diverse disciplines

Research on NWM is not an academic discipline. Rather, I think it is helpful to understand NWM research as a *field* assembled from different sets of concerns, disciplines, and theories. Studies of NWM loosely converge regarding their empirical *study object*, which of course is nuclear waste and how it is managed. While it is indeed the fact that different perspectives – theoretical and conceptual – inhabit this field, it is still relevant to first make a few overarching observations about general tendencies and convergences that exceed mere joint empirical ambitions, and that exist despite some degree of diversity.

Importantly, efforts have been made to synthesize the achievements in the field through recurring systematic reviews – one approximately a decade ago (Solomon et al. 2010), and one more recently (Hietala and Geysmans 2020). These reviews articulate some of the problematics I would like to consider, but I also intend to eventually complement these reviews – particularly the most recent one – by elaborating on an alternative view of the nature of previous research, what previous research might be lacking, how this thesis contributes to the field, and the field's future.

1970–2010: Three consecutive waves of research

The two existing systematic reviews are very helpful for understanding the field, more broadly. First, Solomon et al. (2010) identified three overlapping time periods within which the social sciences have conducted more or less convergent studies. First, 'from the mid-1970s to the early 1980s, initial research explored institutional dimensions of nuclear waste, among other subjects, while several countries attempted to officially solve the problem' (Solomon et al. 2010, p. 1). This was a period of research when critical remarks about nuclear power were surfacing in the public discourse. Importantly, since nuclear waste was not at first identified as problematic in accordance with prevailing technological optimism, the shift to awareness of the dangers of long-term radiation prompted states and administrations to respond to the new concerns. Hence, nuclear waste was increasingly considered an issue also relevant to the social sciences, that is, not as a mere technical issue for technical disciplines to resolve. Nuclear waste was recognized as implying problems beyond the strictly technical.

Indeed, NWM touched on a range of social issues. With pre-existing empirical and theoretical competence in the study of organizations, social movements, and so forth, social scientists were also able to deploy their concepts in the analysis of NWM. This is important, because it opened the nuclear waste issue to broader scrutiny and critical contemplation beyond the isolated forums of natural scientists.

Consequently, this 'first wave' of NWM studies showed the feasibility of addressing issues beyond the strictly technical, by means of social-scientific methods and theories. With this lesson learned, opening up NWM to social-scientific analyses implied even greater opportunities to conduct research. Simultaneously, research conditioned how NWM developed and progressed. As societal tendencies and NWM strategies shifted, so did the focus of the social sciences.

Although organizational aspects of NWM and issues of ethics are recurring topics of study, research after the first period identified by Solomon et al. (2010) followed developments in the wake of the first attempts to actually 'solve' the waste issue. As experts and policymakers eventually appeared to agree on the merits of geological disposal over alternative solutions such as deep boreholes, space launches, and dry storage (e.g., KBS 1978a, 1978b), the 'second wave' of research marks an era when key actors in NWM sought to *site* their disposal facilities as a step towards a 'definitive solution' to the waste problem. As policies shifted from recognizing the problems of waste management, they eventually moved on to seeking to resolve the problems in *practice*. The social sciences followed this development closely:

> The second period began in the early 1980s with a concerted effort to site nuclear waste repositories, and ended in the mid-1990s with some progress in Sweden, Finland, and the United States, and general stalemate elsewhere. This period accelerated research on risk perception and stigma of nuclear waste, and elevated a focus on public trust. Special attention was given to repository siting conflicts in particular. (Solomon et al. 2010, p. 13)

This means that while policy advanced and made claims about resolving the problems identified after the realization that waste management was not just a mere technical issue, the social sciences studied the consequences and results of the implementation and siting endeavours.

As the review authors noted, this period was characterized by conflict. As a rule of thumb, local publics that were subject to site investigations – that is, potential candidates for hosting repositories – were resisting the siting efforts (e.g., Shelley et al. 1988; Barthe et al. 2020). Opposition has proven to be pervasive, and the difficulties of siting repositories are still widely known today. Local opposition is a real obstacle to repository implementation (e.g., Bell 2021).

These experienced difficulties of realizing the more 'practically' oriented policies have in turn prompted some social scientists not just to *study* the conflict, but also to contemplate ways to potentially *overcome* stalemate and controversy. Alongside such research, attention has also been directed to the ethical issues implied by nuclear waste and repository siting processes. The review authors identified this shift in a 'third wave' of NWM studies:

> The last period, since the mid-1990s, has been characterized by failure and continuing political stalemate, with the major exception of Scandinavia, and increased attention to public participation, political systems, and international solutions. Questions of ethics have been given serious attention, while research on risk perceptions and siting conflicts continues. (Solomon et al. 2010, p. 13)

Research following these experiences identified a range of problems, from how to handle and understand ethical issues associated with NWM (Andrén 2012; Bråkenhielm 2015) to how to make siting procedures 'fairer' (Krütli et al. 2012; Bell 2021), and also explored how to study local residents' concrete reasons for resisting or accepting implementation (Wolsink et al. 2009).

The diversity of views of a range of NWM issues, and the temporal aspects of research notwithstanding, it is still important to note, at the overarching level, that research on NWM has certain theoretical predilections. Much or even most research on NWM has been – and still is – conducted within the field of 'risk management' and 'risk analysis':

> That the lion's share of the reviewed literature is published in the journals *Risk Analysis* and *Journal of Risk Research* reflects that, to a large extent, scholarly social scientific research on [high-level waste and spent

> nuclear fuel] management has been increasingly articulated within the field of risk analysis. (Solomon et al. 2010, p. 36)

I will later return to the implications of this tendency, but here I observe that the dominance of risk analysis and risk management in the empirical scrutiny of NWM leaves room to broaden the scope of investigation both empirically and theoretically. There is a risk that the isolation of NWM research might reinforce the view that NWM is an exceptional case that should be contemplated and analysed outside, for example, energy policy. As such, there is a risk of this isolation reinforcing the radical administrative and organizational separation between NWM and energy policy that I described in my historical account at the start of this thesis.

2010–2020: A fourth wave of research

Returning to the issue at hand, and building on the insights of the first review, Hietala and Geysmans (2020) more recently neatly analysed and summarized research in the wake of the first 'three waves' described above. Essentially, the authors identified three additional categories of research since 2010: '1) individual(ized) perceptions about risks, benefits and acceptance of RWM [i.e., radioactive waste management] facilities; 2) governance approaches in RWM; and 3) ethical and epistemological issues connected to RWM' (Hietala and Geysmans 2020, p. 2). To speak in terms of 'waves', these three fields of inquiry can be said to constitute a 'fourth wave' of NWM studies.

First, the authors noted that 'given that the implementation of NWM solutions has been difficult, it is perhaps unsurprising that the underlying issue connecting much of the literature we have reviewed here is the acceptance/acceptability of RWM solutions' (Hietala and Geysmans 2020, p. 10). Still, much contemporary research focuses on 'individual(ized) perceptions about risks, benefits and facility siting' (Hietala and Geysmans 2020, p. 1). Concretely, this research may entail – by means of quantitative methods – identifying the variables that explain why certain communities are more positive than others towards hosting repositories (Sjöberg 2009), how various siting procedures affect local residents' degree of 'acceptance' (Vilhunen et al. 2019), or how levels of 'trust' may or may not explain publics' attitudes to repositories for spent nuclear fuel (e.g., Di Nucci et al. 2022; Seidl et al. 2022).

The second category – consisting of 'governance approaches' – also touches on a variety of themes in NWM, such as empirical and critical analyses of democratic procedures (Sundqvist 2014) and theoretical works on public participation (e.g., Parotte and Delvenne 2015; Rossignol et al. 2017; Svačina 2017).

The third category of research has touched on issues of *ethics* relating to, for example, temporality and responsibility (e.g., Andrén 2012; Oughton and Howard 2012; Taebi 2012; Bråkenhielm 2015). Importantly, this research stream has identified the *perpetual* problems implied by the material properties of nuclear waste, for example, the incommensurability of 'intra-generational' and 'inter-generational' equity, a dilemma to which there is no 'best' solution (Okrent and Pidgeon 2000).

These insights are valuable for getting an overview of the field of NWM studies, and I have no immediate objections to the overall assertions and observations. The question of what the achievements and blind spots of this body of research imply for future research undertakings, however, is one that I propose can be subjected to deeper consideration.

In what follows, I critically discuss how the future of NWM studies has been or could be envisioned by scholars in the field. It is my hope and intention that the plausibility of my suggestions is substantiated by the studies compiled in this thesis, that is, that these studies constitute a credible basis for moving in other directions in studies of NWM than have typically been proposed. Below, I describe in more detail how I have sought to make sense of the field of NWM, and how I have positioned myself in relation to it.

2020 and onwards: A 'fifth wave' of research?

Individual studies typically contain the customary recommendations for future research, given the implications of their findings. However, there have not been many explicit attempts to steer the entire field of NWM research in certain directions. In addition to addressing the state of current research, therefore, Hietala and Geysmans (2020) also made a somewhat rare attempt to provide recommendations for future research to the *entire* field of NWM studies. Because of the rarity of this attempt and its ambition to speak to the entire field, I think it constitutes a good point of departure for discussing what *could* be the focus of future studies of NWM. In so doing, it is my intention to illustrate more concretely that there is an array of options for scholars to choose from when contemplating future research. In what follows, I will first account for the contents of the review authors' propositions and, second, illustrate the possibility of supplementing them.

The review authors' central argument regarding future research is twofold and is grounded in an overview of previous research. First, they argued that social studies of NWM have contributed to upholding the 'sociotechnical divide' because the 'social sciences tend to shy away from the technical aspects of RWM and focus more on the social processes around RWM, thus reinforcing a divide between the social and the technical' (Hietala and Geysmans 2020, p. 2). For

example, the authors concluded that NWM scholars have been too preoccupied with 'acceptance' of NWM facilities. The fact that scholars 'focus on the processes around NWM technologies helps to cement the notion that the main challenge to the implementation of these technologies is public acceptance. Although [previous studies] discuss the implementation of NWM technologies as a sociotechnical challenge, we argue that the focus of these texts contributes to the maintenance of the division between the "social" and "technical" aspects of RWM' (Hietala and Geysmans 2020, p. 7).

Second, because of this supposedly undesirable divide, social scientists should engage in more introspection to bridge it. This observation and the associated analytical prescription have implications for future research. The authors stated that achieving geological disposal technologies 'if they indeed are considered acceptable requires an interdisciplinary approach' (Hietala and Geysmans 2020, p. 11). Accordingly, the authors advocated methodologies that move 'beyond the social/natural sciences divide' which in turn requires 'a recognition of the relevance of broad expertise, and engagement with epistemologies and ontologies beyond narrow disciplinary borders' (Hietala and Geysmans 2020, p. 11). Note that this does not refer to collaboration across the disciplines of the *social* sciences; rather, it is an ambition to integrate the natural and social sciences.

Clearly, the call for interdisciplinarity and bridging the sociotechnical divide is just *one* potential direction for future research. While I agree that there is a preoccupation with 'acceptance' in the NWM field, I do not think that interdisciplinarity is the only way to broaden the scope. Since my work in this thesis corresponds quite poorly with the review authors' propositions, it appears necessary to elaborate on this thesis' raison d'être in the field, more broadly, defending the rationale of my own choices and scholarly propositions.

My main argument, following the discussion later in this manuscript, is that a unified NWM research approach based on Hietala and Geysmans's (2020) conception of future NWM research offers little encouragement to explore the contact points between NWM studies and other fields of (social) research and thus risks missing valuable insights from colleagues elsewhere.

I simply do not think that the social sciences have 'exhausted' their analytical potential. On the contrary, the emphasis on risk management and risk analysis in the NWM field implies an opportunity to explore otherwise scarcely used concepts derived from the social sciences in new ways and using new empirical materials. By moving in this direction, I also think that there is the possibility to help counteract the academic, organizational, and administrative isolation that I have shown characterizes the NWM research field. In essence, issues of NWM touch on an array of issues – theoretical, methodological, and more – of which other realms of the social sciences

have considerable experience. In this particular sense, I agree with Durant (2015, p. 458), who previously offered the insight that 'there is very little that is exceptional or unique about the nuclear waste disposal debate'. Below, I will elaborate on how *I* understand the relationship between previous research in the field of NWM and this thesis. In doing so, I will focus on the humanities and social sciences.

A critical take on the fifth wave of research

When contemplating the position of this thesis in relation to existing studies – and by extension its contributions – I have considered a set of questions to be useful. In turn, I foresee these questions as potentially encompassing a greater richness of detail than do the recommendations for research described above. As such, the following remarks should be read as an attempt to increase the number of pathways that studies of NWM *could* (and sometimes should) take.

To start, what is the raison d'être of fields of research? What are their objectives? What *should* their objectives be? For whom is research conducted? What different answers might follow from these questions? In addressing these overarching questions, I have been inspired by Burawoy (2005), whom I think provides a good basis for at least starting to approach research reflexively, in a way that I think studies of NWM could benefit from. While Burawoy turned specifically to the broad and diverse discipline of sociology, and while his audience comprises sociologists, in what follows I will use some of his insights as analytical tools for discussing NWM studies, offering an alternative view of the nature of previous research, and its future.

My main point is to illustrate that different styles of research produce rather different answers to Burawoy's two crucial questions, namely, 'sociology for Whom?' and 'sociology for What?', which, for my purposes could be rephrased as 'NWM studies for Whom' and 'NWM studies for What?' (Burawoy 2005, pp. 10–11). By acknowledging the possibility of different answers, it becomes possible to distinguish between – and categorize – various sets of research in ways divergent from the previous examples I have accounted for.

Concretely, Burawoy illustrates his points by showing how the categories of *knowledge*, *truth*, *legitimacy*, *accountability*, *politics*, and *pathology* function differently in his four styles of sociology: professional sociology, critical sociology, policy sociology, and public sociology. Thus, what constitutes 'good' knowledge, what determines truth, what brings legitimacy, what amounts to accountability, disciplines' notions of politics, and the research styles' respective potential pathologies differ widely (see Table 1 for an overview).

Table 1. Elaborating on types of sociological knowledge (source: Burawoy 2005, p. 16).

	Academic	***Extra-academic***
Instrumental	***Professional sociology***	***Policy sociology***
Knowledge	Theoretical/empirical	Concrete
Truth	Correspondence	Pragmatic
Legitimacy	Scientific norms	Effectiveness
Accountability	Peers	Clients
Politics	Professional self-interest	Policy intervention
Pathology	Self-referentiality	Servility
Reflexive	***Critical sociology***	***Public sociology***
Knowledge	Foundational	Communicative
Truth	Normative	Consensus
Legitimacy	Moral vision	Relevance
Accountability	Critical intellectuals	Designated publics
Politics	Internal debate	Public dialogue
Pathology	Dogmatism	Faddishness

In light of Burawoy, then, it appears as though much contemporary risk research can roughly be understood as situated in the top-right category – that is, 'policy NWM research', reformulated for my purposes. As Burawoy (2005, p. 9) put it, there is a certain rationale underlying this category of research, because it is often conducted 'in the service of a goal defined by a client' and as such its 'raison d'être is to provide solutions to problems that are presented to us, or to legitimate solutions that have already been reached' (Burawoy 2005, p. 9).

By this, I mean that while plenty of studies cannot be categorized as belonging to this category of research, it is nonetheless my understanding that a substantial number of contemporary studies of NWM seek to make themselves useful for concrete policy purposes. For example, they may seek to inform and facilitate siting processes by means of ameliorating conflict, assuming that lack of conflict means equilibrium of power (see Study III for a critique of this development). One might add that the *pathology* of this project risks being *servility*, because it tends to downplay the need for social–critical analysis of the nuclear industry's and implementers' undertakings, instead adopting the problem formulations provided by these actors – namely, the clients – themselves.

The new context that I sketched earlier in this thesis frame arguably testifies to a greater set of problematics than can be addressed by policy-oriented NWM studies. The techno–political function of nuclear power has new relevance as it is ascribed central importance for greenhouse gas mitigation. The crucial function of NWM to safeguard the back end of the fuel cycle is thus re-emphasized. However, this is a connection that the social sciences surprisingly seldom make. Instead, the nuclear energy industry's achievement of separating the waste issue from energy

production – both materially and discursively (Anshelm 2006) – is echoed in the social-scientific literature, in which waste issues are often analysed outside the realm of broader energy policy and conflict. If the social sciences are to engage more wholeheartedly in transdisciplinary work, as Hietala and Geysmans (2020) have advocated, there is the risk that the social sciences will merely reproduce the artificial divide between nuclear power and nuclear waste.

To sum up, by borrowing from Burawoy and identifying research to which I would like to speak, I hope to demonstrate that there are many possibilities for research lying beyond what has previously been suggested. In doing so, my main points are as follows. First, I do not intend to suggest imposing any 'bans' on research but rather encourage broadening the scope of NWM studies in ways that have yet to be considered.

Second, I have implied taking a research route that promotes a lessened emphasis on being policy relevant and an increased emphasis on *critique*. Third, this route also proposes a lessened focus on interdisciplinarity between the natural and social sciences in favour of safeguarding social-scientific independence. This does not mean that disciplinary boundaries within the social sciences are to be safeguarded but rather encourages collaboration between diverse theoretical traditions. Fourth, I also argue that the research I will present as the foundational inspiration of this thesis would be a potential victim of Hietala and Geysmans's (2020) proposed research route, because it poorly answers the call to bridge the social/natural science divide. Below, I explain why I think this is so.

Building on critical–professional research

To be clear, the above assertions not only specify the *position* of this thesis in relation to previous research, but also should be understood as identifying a few blind spots that I have sought to shed light on. Hence, the main contribution of this thesis is its focus on critique of NWM, that is, a component of previous research that I have argued is underdeveloped. This critical take on NWM, however, would not be possible without pre-existing insights and scholarly work, some of which I will discuss below.

I have been inspired by research that aims to be primarily *reflexive* and *critical* rather than policy oriented. From the perspective of Burawoy, I think that a particular research stream *within* the field of NWM – that is relevant to my purposes – can be better discerned and delineated. My intention at this point is *not* to say what future studies should do, although this may be implied by my undertakings, but rather to provide the reader with a rationale for *my* assertions and choices. With Burawoy's categories of 'critical' and 'professional' research in mind, I have sought to

extract what in previous studies corresponds to the contents of these two categories. Essentially, these are the aspects of research that I have sought to build on, either explicitly or implicitly.

Concretely, I have paid most attention to studies that are reflexively normative, that accentuate the normative aspects of waste management, that do not shy away from highlighting the perpetual problems with NWM, that are not driven by the urge to facilitate the successful implementation of geological disposal, and that conceptualize NWM as a phenomenon much broader than just the empirical realm – that it is a field that actualizes a broad range of sociotechnical problematics. I think that the genealogy of this thesis is best understood in the context of studies that possess such characteristics. The following representative, but far from exhaustive, examples will illustrate this.

First, in contrast to what much policy-oriented research seems to acknowledge today, a perspective on which this thesis builds is that NWM is a 'wicked problem' – that is, a problem to which there is no definitive answer, only a variety of suboptimal options to choose from (Rittel and Webber 1973). NWM has rightly been identified as such a problem (Bergmans et al. 2008). Much contemporary NWM research has abandoned the concept of 'problem' (it is now much more common to speak of 'challenges'), implying that NWM is a kind of hurdle that can be overcome if just approached and taken up appropriately (e.g., Dawson and Darst 2006).

Second, in addition to this fundamental point of departure, the contemporary context in which NWM is situated is historically contingent, yet much contemporary research is devoid of historical contextualization. As such, I have emphasized research that has provided crucial historically contextualized insights into the complexity of conflicts over NWM and nuclear power. Particularly in relation to the Swedish case, the work of Anshelm (2000) and Sundqvist (2002) about Sweden's nuclear history, as well as its nuclear waste history (Anshelm 2006), has provided invaluable insights into complex historical events, and detailed descriptions and analyses of historic happenings that have been of foundational importance for 'setting the scene' for my purposes.

I have also greatly appreciated analyses of the temporality of public involvement and engagement in issues related to NWM (Anshelm and Galis 2011). Without these insights, it would be truly impossible to understand the state of NWM today. The same can be said of studies that have focused more on NWM internationally, and especially on how siting actors have *evolved* in their attempts to site repositories by engaging in public participation and stakeholder engagement (e.g., Sundqvist and Elam 2010; Bergmans et al. 2015). Once again, understanding the progression of NWM would be impossible without these insights, and without them the studies compiled in this thesis would be contextually lacking.

I have also derived great practical benefit from studies highlighting the contextual contingency of individual national NWM programmes. For example, I have learned much from research that has contributed insights into the legislative and formally political factors that condition the development of NWM facilities and technologies (e.g., Brunnengräber et al. 2015; Litmanen et al. 2017).

I have furthermore learned much from theoretical exercises in technocracy critique. This work has contributed core insights into the remaining democratic issues related to NWM, despite increased participation (Blowers and Sundqvist 2010). This includes the observation that the technocratic Swedish model of NWM has also been successful internationally because of its alleged democratic essence (Elam and Sundqvist 2009), that is, the very starting point of this thesis.

Finally, I have learned much from intra-field critique of NWM. I have come to share the view that the form of social science that focuses on questions of how opinion is formed, and that uncritically accepts 'the technical' as the domain of technical experts, can be criticized for functioning as an aid for struggling companies and states striving to implement geological disposal (Sundqvist and Elam 2009). Accordingly, what are needed are perspectives that can be used to investigate technical actors' actions even if these actions are legitimized with reference to scientific objectivity. I will subsequently develop my own understanding of these existing assertions.

In sum, the above examples constitute what Burawoy would call 'professional' or 'critical' forms of research. I do not intend to make any sharp distinction between these categories, but merely make the point that I have built on – and sought to contribute to – research that is reflexively normative, that understands truth as at least in part normative, that seeks to establish intra-social-scientific debate, and that understands NWM as a field that can generate important knowledge of society beyond the confines of its isolated administrations. I do not wish to claim that this project is without its own potential pathologies, but I think it constitutes a rare reflexive and critical attempt to relate to the field of NWM, an attempt that does not constitute a dominant force in the totality of the literature on NWM.

In what follows, I will elaborate in more detail on how I have sought to develop a theoretical approach that honours the research principles I have argued for above. My point of departure for doing so will be STS, a field that I consider as possessing the capacity to advance Burawoy's two research categories of professional and critical research. However, since it is my understanding that this field comes in many forms, I think it is necessary to be more precise

about the form of STS that I will eventually settle on and how it could advance critical studies of NWM.

4 Critical STS for understanding nuclear waste management

Introduction

I situate this thesis in STS because I have conducted social studies of issues related to science and technology, and because I think that science and technology have unique features in modern societies. *Science* and *technology* are distinct enough phenomena in modern societies to justify their own academic branch of critical scrutiny. This is because there is still widespread technological determinism in modern societies: science is still celebrated naively for its objectivity, and hailed for its linear progress devoid of human culture and social interests.

Modern societies are intrinsically technical, which means that there is still merit to Marcuse's (2002, p. 172) claim that 'technology has become the great vehicle of reification' – that is, the fallacy that technological development is devoid of historical contingency, occurring 'outside' of societies' asymmetric power structures. In essence, STS strives to contribute to the values and ideals contained in Burawoy's professional and critical research categories I previously discussed and granted importance, potentially theoretically enriching the field of NWM.

I have, however, deployed STS with the simultaneous intention to juxtapose my central points of departure with at least a few contrasting theoretical alternatives not necessarily from academic realms that consider themselves 'to be' STS. I have thus not been an orthodox STS researcher. Instead, I have adopted David J. Hess's (1997) view that STS cannot (or *should* not) be understood as a *single* theoretical point of departure or as simply the social study of science and technology; rather, it should be regarded as 'an interdisciplinary conversation among a wide range of "constituent disciplines"' (p. 3). By adhering to this view, I have been able to contemplate theory more broadly than in STS, for example, as in various sub-disciplines of sociology. I will elaborate on this matter below.

In addition to treating previous research into NWM as potentially improved by certain theoretical concepts from STS otherwise rarely used, I will eventually also attempt to theoretically elevate the discussion by asking how the nature of NWM might actualize theoretical concerns *within* contemporary STS itself – that is, if one can imagine the concerns of my project potentially helping make visible and elaborate on contemporary theoretical matters of interest in the field. I will subsequently ask what in the empirical nature of NWM might actualize and shed light on such contemporary theoretical tensions, concerns, and ambiguities in STS. In what follows, however, I will first discuss the theoretical concepts I have chosen to deploy.

Tensions in STS: Radical heterogeneity vs. overarching concepts

Essentially, I have pursued theory that is partly constructivist, partly realist, partly materialist, and that deploys overarching concepts. STS has constituted a good place to start. As will be shown, I have found that theory that simultaneously encompasses all four of these approaches is not common in STS. However, there are relevant analytical examples that can be understood as situated at the fringes of the field. While actor-network theory (ANT) and post-ANT–style theories may have secured a dominant position in STS, and while 'social constructivism' has been more agenda setting in the past, there are coexisting tendencies that could promote the theoretical rediversification of STS, and that correspond to a greater degree to the forms of theory I have pursued.

In STS there is now an increasing tendency alongside (post-)ANT and social constructivism to attend to the absence – and the reinstating – of a range of neglected theoretical concepts that have been either downplayed or abandoned altogether. As highlighted in Study II, there is increasing focus on 'capitalisms' in STS (Moore 2021), for example, taking account of the 'technoscientific' character of capitalism (Birch 2017) and the 'scientific management of neo-liberalism' (Lave et al. 2010).

I have considered this tendency in STS as potentially shedding light on the main point of departure of this thesis, namely, that NWM constitutes a field that is fundamentally 'inert' and that is heavily discursively, ideologically, and materially conditioned by *pre-existing* factors that exist not only within the confines of the field, but also outside and beyond its immediate context.

A further reason for building on this tendency in STS is my observation that NWM actualizes how we rely – theoretically – on 'multiplicity' or 'totality' when analysing sociotechnical phenomena (Söderberg 2017). A core concern emerging from my work on this dissertation is the degree to which one can rely on 'overarching concepts' as opposed to 'radical heterogeneity' (Söderberg 2016). As Söderberg (2016, p. 185) put it:

> Is the world sufficiently unified and stable over time to be grasped with concepts? This ontological question has bearing on an epistemological question: what explanatory value should be given to overarching, theoretical concepts such as 'society', 'capitalism', 'class' and 'interests'? These questions mark a central divide in the [STS] research community.

While STS surely implies a range of other theoretical inconsistencies and/or conflicts, I have assigned priority to the issue Söderberg raises because it has bearing on the fundamental claims of my core argument. According to my understanding, overarching theoretical concepts equip

scholars with the means to explain the inertia, lack of change, and forms of domination that I think are core characteristics of the empirical material.

To predominantly focus on how reality is messy and how taken-for-granted truths are being challenged would, the way I see it, conceal a core aspect of NWM, which is instead that taken-for-granted truths are *not* being challenged and that reductionist ideas about technical democracy are being naturalized and perpetuated. 'Radical heterogeneity' is, from this perspective, ill-suited for describing my empirical observation that NWM is inherently inert.

To me, what has appeared as a defining feature of NWM is that it has remained sufficiently unified and stable over time, conflicts notwithstanding. To emphasize heterogeneity (to study local practices, 'situated knowledges', and so forth) could make it seem as if the reality of NWM was inherently unstable, could exaggerate the potential for lay agency and downplay the perpetual power asymmetries that I think characterize the field.

When reading the rare STS research that has in fact contemplated the realities of NWM, I have noted that the findings contradict my core claims. For example, Callon et al. (2009) argued that their situated approach – which is close to what Söderberg would call 'radically heterogeneous' – is what frees them from 'a set of categories and grand narratives that conceal, to the point of making invisible, anonymous, collective, stubborn work that, day after day, brings dialogic democracy into existence' (p. 225).

As I elaborate on in Study II, this critique can, on the contrary, be accused of neglecting the stable, overarching patterns of domination that arguably condition sociotechnical arrangements (Saito and Pahk 2016). Hence, I have understood a form of structural thinking as 'especially useful in explaining the nonexistence of certain controversies' (Martin and Richards 1995, p. 519). This is the main reason why I think there are particularly good reasons for adopting overarching concepts, given the nature of the inertia and conditions that characterize NWM.

Overarching concepts are not, however, the sole issue. There are good reasons why one should, simultaneously, be materialist, because the properties of nuclear waste have ***real*** consequences. Some form of partly realist materialism is reasonable to deploy given the nature of nuclear waste. However, in STS most forms of materialism are constituted by theoretical currents that typically reject overarching concepts, and that do not assign priority to inertia. For instance, the core proposition of both ANT and new materialism has been to incorporate matter into the analysis in *specific* ways. They have both tended to stress the 'vitality' of matter, furthermore conceptualizing objects as dependent actors that deserve the status of separate 'units of analysis'. Hence, matter is also represented as heterogeneous. I have not found these ideas

helpful for understanding the empirical material I have gathered. Not because they are uncritical, but because their

> critique is one-sided. They rely on immersion in the vital or spectral world of matter or objects to criticize or subvert our concepts and dichotomies but tend to adopt an uncritical and frequently celebratory attitude toward this world itself. To adopt a critical perspective on this world, and the role played by capitalism in producing it, immersion must be supplemented by distance and a proper deployment of macro-level theoretical concepts. Since environmentally destructive mechanisms are ingrained in the world of matter or objects itself because of the imposition on it of capitalist forms, it is highly problematic to celebrate the vitality of that world. (Cassegård 2021, p. 170)

This quotation summarizes well my core point, that is, that the material nature of nuclear waste does not call for theories that stress *vitality*, *agency*, and *change*, as this would potentially divert attention from the perpetually destructive nature of this waste. While it is true that nuclear waste is volatile in the sense that it is unruly, I have considered it also to be crucial to study those social forces that have *produced* the material in the first place, that have perpetuated the dangers of radiation, and to critique them. In other words, the *lack* of vitality and potential for change is what is essential. I think that focusing on the vitality of matter – in the case of nuclear waste – would also divert attention from those aspects I consider important.

To be sure, in adopting this somewhat rough categorization of the STS community, my point is not to claim that my discussion will be all encompassing: the variety and nuance of STS in reality is far greater – theoretically, empirically, methodologically – than my discussion can possibly accommodate. My point is merely that I think that NWM could shed light on the *particular* theoretical tension mentioned above, that is, *one* important dividing line in STS, the reductionism of my focus notwithstanding. Moreover, my theoretical points of departure may contribute to diversifying STS, especially in relation to the scarce STS interventions that have focused on NWM (e.g., Callon et al. 2009).

What follows describes in more detail how I have navigated the overarching concepts I have understood to be important, and the form of materialism I think contributes to navigating the theoretical tensions in STS sketched above.

Nuclear waste management in the 'technosystem'

My solution to the theoretical problem of how to be materialist without sacrificing overarching categories, while still recognizing *science* and *technology* as distinct features of modernity deserving specialized scrutiny, has been to deploy 'critical constructivism' (Feenberg 2017a, 2017b). This is

a project that seeks to combine Frankfurt School-style critique with STS's empirical case studies (Feenberg 2017a,). As such, critical constructivism proposes a few tenets often associated with critical theory, that is, overarching concepts, while not neglecting matter. Crucially, critical constructivism navigates *constructivism* and *realism* in a specific way.

Critical constructivism also shares my most crucial points: that nuclear waste has emerged as a consequence of capitalism's thirst for energy to produce profit and secure continuous and increased production; and that this endeavour is supported and reinforced by a 'rational' culture and reductionist ideas that nurture certain illusions about the nature and function of technology. These are the beliefs that we are technologically omnipotent, that linear scientific and technological progress will remedy lingering sociotechnical problems, that scientific and technological projects exist 'outside' of social interests, and that technological projects can be decoupled from their broader implications.

In terms of overarching concepts that contemplate assertions such as the above, critical constructivism holds that central to modernity is a rational culture that subsumes social life under a dominant standard of scientific–technical rationality (Feenberg 2017a). Although understanding itself as objective and neutral, technical rationality is biased because it enforces certain values (such as efficiency) by means of calculation and technology. Critical constructivism both reveals and challenges such taken-for-granted values. Inspired by Lukács's concept of *reification* – the process by which the properties of objects appear to independently determine social relations as well – it proposes that 'capitalism imposes a rational culture that privileges technical manipulation over all other relations to reality' (Feenberg 2017a, p. 42).

A key concept in critical constructivism is the 'technosystem', that is, 'the field of technically rational disciplines and operations associated with markets, administrations, and technologies' (Feenberg, 2017a, p. x). I have found this concept helpful for contextualizing NWM more carefully than it contextualizes itself. Technologies – such as repository concepts – are not isolated entities but rely on and perpetuate the often instrumental goals defined by rational institutions such as markets and administrations. Conceptualized in this way, NWM appears as a mere part of a greater whole.

As the instrumental goals promoted in the technosystem are not 'natural', critical constructivism elaborates on the nature of the biases of rationality. Although the technosystem may appear to be all encompassing and claims control over nature, it produces a range of whimsical externalities, or 'causal feedbacks'. According to critical constructivism, interventions in nature by means of technology have real repercussions, as the utilization of nuclear power and its subsequent need for waste management clearly illustrate. Identifying causal feedbacks is

important to critical constructivism; the destructive consequences of sociotechnical systems are not 'external', but constitute real consequences of how the systems are built and operate. Critical constructivism thus holds that the *biases* produced by technical systems should be made into core concerns for scholars of technology.

To be clear, the point is not that modern societies are necessarily maliciously and consciously oppressive (although they sometimes are). While the technosystem may remedy certain forms of 'substantive biases' – for example, *institutionalized* discrimination based on gender or race – it perpetuates so-called formal biases that come in less obvious, often unintended forms. For NWM, this is highly relevant because no one is formally prohibited from participating in stakeholder engagement exercises, yet technical know-how is a crucial skill one must acquire to be viewed as a legitimate actor (see Study II). In this regard, one can claim that NWM has increasingly rid itself of substantive bias, whereas formal biases have emerged in their place. I consider the individual studies compiled in this thesis as shedding light on a range of formal biases that have emerged in the wake of the NWM project.

Despite these general assertions that diverge from many, but not all, points of departure in STS, critical constructivism is not intended to force all study of technology to conform to a universal method. Inspired by STS, critical constructivism is informed by empirical case studies of technology. The 'double aspect of rationality' means that while modernity is characterized by a dominant rational culture, technical rationality is not all encompassing but context bound, with *particular* social and material consequences (Feenberg 2017, p. 63). Hence, local culture plays a significant role in technological development, which underscores the need for *empirical* studies of technology. Put differently, this is an attempt to reconcile micro and macro concepts, but also an attempt to incorporate ANT's criticism of what Callon et al. (2009, p. 225) have called 'grand narratives', that is, overarching concepts that according to ANT conceal the peculiarities of locally situated practices.

The above describes some core ideas of critical constructivism that serve to navigate the tension between overarching concepts and local practices. An additional point of analytical departure in critical constructivism, however, is a particular understanding of matter that seeks to situate technologies in the technosystem itself. Importantly, I have found this form of materialism helpful for understanding how particular objects, technologies, and scientific details are attributed such great importance, while others are ignored. Moreover, this form of materialism solves my core issue, that is, how to be materialist without sacrificing overarching concepts.

Feenberg's (2020) materialism is made more concrete through his 'instrumentalization theory', which presents a way of thinking about objects and a 'general framework for understanding the sociality of technology' (p. 18). According to this theory, recognizing the material properties of objects is important (as they are not *entirely* relative to a social world), but it is equally important to realize that they acquire function in a system of other objects and subjects. In Study II, I use this insight to shed light on the fact that specific corrosion properties of copper gain importance not because of a disinterested quest for metallurgical truth, but because of copper's association with broader issues in NWM.

Two processes – not temporally separated – occur during technological development. In 'causal functionalization', the object is detached from its place in nature and is thus decontextualized (Feenberg 2017, p. 154). It is also reduced in the sense that the totality of its properties is left unexamined: merely a set of useful material properties remain after decontextualization. The object is thereby autonomized, stripped of its social and material associations. Cultural functionalization, on the other hand, is the realization of the object, that is, its recontextualization within existing cultural practices (Feenberg 2017, p. 154). The object is systematized and aligned with other artefacts in a technical system; secondary qualities are ascribed to the object that 'seamlessly embed it in its new social context' (Feenberg 1999, p. 206).

The object is thus not solely material or social, but both. The rules of nature that govern it apply, but the functionalization is achieved through *social processes* conditioned by particular contexts. This is not 'relativism' but takes into account the material limitations of objects. Feenberg's *constructivism* is therefore limited and, in part, *realist*.

From my perspective, these notions and concepts are helpful for understanding NWM beyond the promises of new NWM governance. They situate NWM in a broader context of markets and administrations, making visible the context that conditions NWM but that NWM itself refrains from elaborating on. For instance, the *function* of NWM is at least in part to legitimize nuclear power. Feenberg's conceptualization of objects is also helpful because it, first, considers in realist terms the *constraints* implied by the material properties of waste (there are material limitations about what we can do with the waste), while it simultaneously – in a more constructivist way – shows how objects' properties are reductively conceptualized (constructed) to fit into biased sociotechnical systems. As I will later explain, this view of objects in the technosystem allows me to further elaborate on what can and cannot be changed.

There are, however, some aspects of critical constructivism that I think could be further problematized, given the empirical nature of NWM. A crucial observation concerns the consequences for democracy and public influence given the material properties of nuclear waste. As elaborated on in Study II, NWM testifies to the consequences for democracy of nuclear power and of the technical hubris that nurtures it. Although I have worked according to Feenberg's ontology of objects, I have certain objections to the way he foresees technological change.

Feenberg (2017b) holds that 'the instrumentalization theory finds underdetermination in the structure of rationality itself' (p. 114). This implies a certain room for human agency; technical rationality can potentially be challenged, and overcome. Critical constructivism therefore rejects the 'totalizing, dystopian conclusions' of the Frankfurt School (Feenberg 2017a, p. 42). In this regard, Feenberg once again appears to have been influenced by STS critique of the accuracy of overarching concepts.

Change, more concretely, occurs through so-called democratic interventions (Feenberg 1999, 2017a). These are 'the actions of citizens involved in conflicts over technology' (Feenberg 2017, p. 53) and are 'rooted in … "participant interests" that emerge from specific social contexts. These interests represent values denied by the exclusive emphasis on narrowly conceived instrumental goals in modern societies' (Feenberg, 2017b, p. 99).

In other words, in critical constructivism, laypeople are important agents of change. They often hold vastly different conceptions of technology from those of experts. Feenberg thus discerns increasing lay technological interventions in the technosystem. Explicating technologies' place in the 'life-worlds' of laypeople holds the promise of making 'abstract' technologies more 'concrete'. Essentially, this means a shift from narrowly construed understandings of technologies seen through the lens of technical rationality to a recognition of their broader implications. These broader implications, in turn, are typically revealed by nontechnical or lay actors.

As I note in Study II, however, these ideas about change are off the mark because of the particularities of NWM, and they appear too optimistic in this context. My core point is that if one stays true to the critical theory understanding of matter, then the latitude for what can be seen as 'underdetermined' in NWM shrinks considerably. Thus, I have accepted Feenberg's ontology, but am sceptical of his optimism about change. Rather, I have found that NWM is a field that represents the *irreversible* consequences of capitalism and the technical rationality that underpins it. From this perspective, any claim that NWM governance is inherently democratic

should be viewed with scepticism: the prospects of technical democracy were circumscribed the moment spent nuclear fuel was first produced.

In essence, the deployment of critical constructivism together with a sceptical understanding of its ideas about change has enabled a few conclusions that I think are not predominant in previous research on NWM. As I will discuss at greater length in the conclusions, the thesis as a whole testifies to the *inevitable* limitations regarding change in NWM, while much existing literature has downplayed such inevitability.

Critical constructivism and the individual studies

Rather than explaining in detail the theoretical contents of the individual studies, I conclude this theoretical section by establishing that the overarching theoretical issues in STS treated above should be understood as the framework in which the individual studies are situated. What I hope to illustrate is that a focus on divergence and radical heterogeneity could obscure the structural factors that I have argued heavily condition NWM, and that have *real* consequences for how NWM can and cannot be conducted.

My intention at this point is not to reiterate the theoretical specifics of each study. Instead, I will briefly explain how I understand the relationship between each individual study and the overarching framework of critical constructivism. Admittedly, the studies compiled in this thesis do not perfectly uphold the ontological and epistemological principles of critical constructivism, or its broader research programme. Rather, the contents of this thesis frame are better understood as my current location – at this specific time – during a continuous movement from dominant theoretical traditions in STS in the *direction* of critical theory. In this sense, I have not been theoretically orthodox while working on this thesis.

Yet in each study there is more or less overlap with critical constructivism. For example, Study I elaborates on the broader implications of technology, and on how such implications are concealed by means of technological solutions. I have considered this analysis as corresponding to critical constructivism's view of technologies as embedded in broader systems of markets and technologies. In this study, we seek to demonstrate that political ideas, markets, and rational organizations influence the course of technological development, which is not necessarily determined. What is required to keep such a project together, despite its tensions and ambiguities, is a range of reductionist ideas that can be considered equivalent to technical rationality.

Study II is explicitly related to critical constructivism and has clearer theoretical ambitions than do the other studies. At this point it appears redundant to elaborate on its relevance to critical constructivism: the study can be evaluated on its own merits as perhaps contributing to critical constructivism and STS more broadly.

Study III treats the domination of technical rationality – a core tenet of critical constructivism – as more or less consistent with other forms of Marxist understandings of power. 'But why should one exclude the possibility that power may be at work in such a way as to secure consent and thus prevent conflict from arising?' (Lukes 2021, p. 11) – this question has at least initiated contemplation of how the dominance of technical rationality takes practical forms, in my case in the siting of a repository in the municipality of Östhammar, Sweden. In what Lukes (2021) calls the 'third dimension of power', I have understood the ideological influence that powerful actors exert to make other actors behave in a way that they would not otherwise do as an important aspect of how progress is achieved in NWM.

Although *emotions* are not a core concern in critical constructivism, I do not think there is anything that would prohibit elaborating on the experiences of technology that exceed presumptuously rational accounts of how one 'should' and 'should not' feel about nuclear waste and NWM. As such, Study IV contributes to questioning powerful actors that rely on a presumptuous form of rationality. For example, while the "Enlightenment taught us to identify bias where prejudices, emotions, and pseudo-facts influence judgments that ought to be based on rational standards" (Feenberg 2017a, p. 22), we identify, just as critical constructivism does, that rational standards too can be prejudiced. In this sense, a form of rationality that rejects emotions as relying on a variety of myths is in itself mythical because it fetishizes its own neutrality.

Theoretical conclusions and discussion

By invoking critical constructivism, I have – with a few caveats – claimed that it is possible to put to use a form of materialism that does not shy away from utilizing overarching concepts. In contemporary STS, this is a position that is not currently dominant. Hence, the thesis seeks to strengthen this position in STS.

Critical constructivism, however, also has clearer empirical ambitions than did its critical predecessors, which implies a need to demonstrate in greater detail how empirical studies of technical rationality can be performed in scholarly practice. In relation to methodology, critical constructivism offers little practical guidance. According to Feenberg (2017a, p. 61), it is only

possible to make a few overarching suggestions 'because that is the most that a formal methodology can provide. In the end there is no substitute for insight, which cannot be formalized'. Whether I provide insight is for the reader to decide, but my analytical procedure has still relied on a few formal methodological principles that I have derived from approaches other than critical constructivism. In what follows, I describe in more detail the nature of the empirical material, and how I have analysed it.

5 Studying multi-sited nuclear waste management empirically

Introduction

Issues related to NWM are not concentrated in a single arena; rather, NWM is 'multi-sited' (Hess 2001). This has methodological implications, as the researcher must choose which arenas to focus on, and which to not focus on, and crucially the researcher must adapt the methods depending on the nature of the arena. This thesis illustrates this as it attends to multiple, somewhat divergent arenas in which issues of NWM are debated, agreed on, advanced, or indeed contested. In this sense, the sum of the articles is greater than the individual parts: together they illustrate that NWM has much broader implications than the discourse typically admits.

I have used different methods depending on the context in which I conducted research. Mainly, however, I have relied on observations and document analysis. My rationale for doing so has been that while documents offer good insights into the discursive patterns, problem representations, and hegemonic ideas of NWM, they do not tell the whole story of how events unfold in *practice*. Thus, it appeared suitable to also observe turns of events that coexist with the discursive patterns to identify discrepancies between *what the problem is represented to be* (e.g., Bacchi 2012) and how such problems are addressed and 'resolved' in practice. Moreover, I have conducted my work based on the premise that the problems *represented* in documents should always be juxtaposed with competing ideas and problem representations, that is, critical contemplation and imagination.

In what follows, I will first account for the particular data on which the articles compiled in this thesis are based, to provide the reader with an overview of the extent, scope, and nature of the empirical material. I will alternately discuss the benefits, downsides, and implications of the different methods used to gather the empirical material, and discuss the limitations of the data. Second, I will account for my analytical procedures. Third, I will contemplate various ethical concerns implied by the specifics of my project.

Four sites of inquiry

Each article represents a 'site' in which NWM operates. In terms of temporality, I have ordered the articles compiled in this thesis chronologically in *the order in which I started writing them*, which is

not necessarily in the order they were submitted and/or published, or according to any thematic sequence. I think this order better illustrates how *I* have moved from site to site, my rationale for doing so, and how I have deepened my understanding of the field while conducting research. In what follows, I will alternately describe the nature of the sites, describe the data collected there, and discuss the methods deployed.

Sites 1 and 2: European technology coordination and NWM in a Swedish court

The first article was written based on my participation in a multilateral EU project, Modern2020 (Modern2020 2015a, 2016). I was recruited to the PhD programme specifically for the purpose of conducting research on this project. Originally, it was expected that this thesis would constitute a more extensive scholarly scrutiny of Modern2020; I did not live up to this expectation, and to that matter I will return.

In the project, I and sociology colleagues from the universities of Gothenburg and Antwerp constituted one of several work packages, each of which had different tasks within the project. Together, the work packages were expected to realize the overarching aim of Modern2020, which was to 'provide the means for developing and implementing an effective and efficient repository operational monitoring programme, that will be driven by safety case needs, and that will take into account the requirements of specific national contexts' (Modern2020 2015a). We describe the problematics the project actualized in more detail in Study I.

Our work package's specific task was to facilitate 'public stakeholder participation' (WP5 2014) in the development of monitoring technologies, whereas other work packages worked on concrete technical monitoring solutions, technical standards, and more. We, the sociologists, were part of the project over its entire duration of four years (2015–2019).

In our work, we had insight into the everyday business of the ongoing project communications and tasks: e-mail lists, a joint database for reports, online and offline meetings, and so on. The project also required some travelling and meetings, during which I kept field notes, occasionally made recordings, and gathered documents. Since the project is now officially completed, there is a wide range of public reports of the project results available that we incorporate in our analyses in Study I. More importantly, since I conducted participant observation, I was able to study the processes leading up to the results finally presented by the project partners; researchers get much better insight into the practices of technologies-in-the-making when studying them in real time, than they do after the fact (Sismondo 2010).

In concrete terms, I spent over 30 full days in project meetings and workshops across Europe, contributed to various project documents, collaborated with the nuclear industry, and more. Below, I summarize the most central parts of my project engagement during which I observed and participated:

Table 2.

Empirical material, Modern2020				
Stockholm	1–3 December 2015	Project meeting	Participant observation	***3 days***
Zürich	22–24 February 2016	Project meeting	Participant observation	***3 days***
Äspö laboratory	12 April 2016	Personal tour	Participant observation	***1 day***
Östhammar	15–16 May 2017	Workshop	Participant observation	***2 days***
Oakham	13–17 June 2017	Project meeting	Participant observation	***5 days***
Prague	27–29 September 2017	General assembly	Participant observation	***3 days***
Paris	29 November–1 December 2017	Workshop	Participant observation	***3 days***
Antwerp	1–3 February 2017	Workshop		***4 days***
Paris	28 February–2 March 2017	Workshop	Participant observation	***3 days***
Uppsala	27 February–1 March 2018	Project meeting	Participant observation	***3 days***
Sargans	4–6 June 2018	General assembly	Participant observation	***3 days***
		Project survey	Document analysis	
		Project reports	Document analysis	
Total:				***33 days***

In working on Modern2020, I and my sociology colleagues functioned as project 'communicators': intermediaries between national host communities in Sweden, Belgium, and Finland, and the project's technical tasks and overarching aims. Primarily, I was working with the municipality of Östhammar – the Swedish designated host community for the final disposal of spent nuclear fuel (Johansson 2021) – in a variety of ways. For example, we organized collaboration between Modern2020 and the municipal politicians via the municipal public officials' office. We organized a workshop in Östhammar on the topic of 'passive safety' and monitoring that both nuclear industry representatives and municipal politicians attended. I have not scholarly engaged in a concrete way with the material produced during this collaboration, but the experience has still provided extensive insights into the practices of NWM and the culture in which it is embedded.

While it is easy to quantify the number of days spent in meetings and workshops, it is more difficult to concretize the contextual knowledge gained through attending these functions. Still, I would argue that this contextual knowledge has been crucial. At the very start of my PhD education, I started working on the project; access was not an obstacle. On a positive note, my participation in Modern2020 threw me straight into the 'hub' of NWM – a 'baptism of fire' if you will – giving me crucial insights into the field. My participation helped me immensely to form an awareness of the key actors, of what they did and did not speak of; it taught me the politics of NWM, and I became familiar with the esoteric language spoken by those central in the field. As dull as I may have found these NWM terms and concepts, they had to be grasped in order to understand NWM.

Moreover, participating in Modern2020 also taught me the conditionality of international EU techno–political projects, a lesson crucial for my subsequent work. As described in Study I, any EU policy-related project is heavily conditioned by existing energy policy, established technologies, and so on – they are path dependent and locked in. Hence, I never viewed Modern2020 as holding any substantial prospects for change, even though the project itself spoke warmly of 'stakeholder engagement'. For these reasons, I have come to consider any facilitating of public participation as deserving considerable scepticism given the 'standardization frameworks' provided by the EC that guide technical development in the EU (e.g., European Commission 2020). As such, I uphold the conception that the 'realpolitik' of nuclear risk is characterized by the fact that 'political expediency trumps technical democracy' (Saito et al. 2016, p. 5).

There are good reasons to view social-science contributions in these contexts as alibis for realizing locked-in policies and technologies. This insight, however, left me with a feeling of

alienation. Consequently, I saw it as necessary to broaden the scope of my inquiries and explore the contemporary Swedish national scene, where important events were about to occur. This was my attempt to escape the restrictions of Modern2020 that I had experienced.

In 2017, the nuclear industry application to build a repository for spent nuclear fuel in the municipality of Östhammar was to be tried in a Swedish court of law (SKB 2011a, 2011b, 2011c; Land and Environmental Court 2017). Initially, I had no intention of participating, but given my experiences of Modern2020, I saw the court procedure as an opportunity to circumvent the constraints of the project and more unconditionally approach NWM, even in relation to problematics beyond the international policy arena. In other words, this study was a deviation from my Modern2020 duties. Below, I quantify the extent of my participation in the Land and Environmental Court:

Table 3.

Empirical material, Land and Environmental Court				
Stockholm	5–14 September 2017	Negotiations	Observations	***8 days***
Östhammar	8–13 October 2017	Negotiations	Observations	***5 days***
Stockholm	22–26 October 2017	Negotiations	Observations	***4 days***
Documents	Before, during, and after negotiations	Plaintiff correspondence	Document analysis	
Total:				***17 days***

In Court, my ambition was primarily to capture what was being said, to arrive at an understanding of the different parties' strategies and of how they used scientific knowledge to advance their social interests and concerns. While I did this work without any concrete ideas about how to make sense of what was happening, my preconception was that the corrosion controversy elaborated on in Study II would be crucial, and that there were *sociological* explanations for the scientific preoccupation.

However, I sought to make my *descriptions* of the turns of events as strict as possible, striving not to impose any particular theoretical point of departure. At first, I made brief notes with pen and paper during the hearings, notes that I subsequently refined and expanded into richer field notes on the computer in the evening. However, this was very time consuming. Eventually, I realized that the Court procedure meant that we were all seated throughout the time we were in attendance (except during the field visits), which meant that I could develop quite rich field notes on the computer as we went along.

To get more out of the field notes than one would from, for example, meeting minutes, I strove to capture both what was being *said* and how people *reacted* to what was being said. My idea was that these reactions would be indicative of what was most important to the actors. Moreover, I sought to make particular notes of when I felt that the data had become somewhat unclear, when I was paraphrasing rather than quoting, and so forth. Below, I provide an excerpt that illustrates the field notes I developed, and the information they contain:

> Elementary thermodynamics contradicts what SKB and Uppsala claim, he says. Peter introduces the 'sauna effect', which, according to him, will lead to the clay that surrounds the canister cracking and eventually exposing it. 'Not all canisters will fail, but some will, and some, in this context, are a lot'. Peter turns to the Swedish Radiation Safety Authority: 'How can they approve of this?' 'Their internal experts have warned them, we have warned them'. The only reasonable conclusion that can be drawn from science is 'disproven!' Peter brings up a new PowerPoint slide and now shows a contract between SKB and the Uppsala researchers. In the colour red he has underlined the parts of the contract that, according to him, are particularly troubling. In particular, he has highlighted a passage stating that SKB will be allowed to handle the material from the experiments as they see fit (the above is rough paraphrasing, see Peter's presentation for the exact quotations). The participants from the environmental movement are shocked by this claim, and there is an audible gasp coming from their section of the courtroom. Mats Boman, Uppsala researcher, who is sitting right next to me is also noticeably upset by Peter invoking the contract, but for different reasons. He waves to the SKB personnel who function as stewards in the Court, demanding that they give him the microphone.

I also audio-recorded every session I observed, for two reasons. First, I thought that the events were significant enough to honour by recording them for future reference, future research, and so on. Second, I wanted to be able to 'synchronize' my field notes with the audio so that it would be easy for me to move between the different types of materials. In the end, I did not much use the audio-recordings for the articles. However, there are empirical quotations in Study II developed from the audio-recordings, in which I transcribed the words uttered in Court verbatim rather than paraphrasing them, as I had often done in the field notes. In doing so, I kept the specificity of what had actually been said in session.

Finally, I would like to recognize that there is no single meaning of ethnography, which has widely varying meanings across disciplines (Hess 2001). In STS, the field in which I am schooled, ethnography is and has been the hallmark of good methodology (Beaulieu 2010), but arguably carries a different meaning than in, for example, anthropology. It is more relevant here to speak of 'observations', that is, not ethnography or participant observation in the stricter senses of the terms. My main reason for observing has been to study events as they occur in their 'natural' setting. In doing so, I have been inspired by STS case studies. Famously, ethnography once showcased the possibility of studying scientific knowledge in the making, in turn transforming

the conception of *science* as a self-evolving entity radically divorced from the lives of humans, into an object embedded in culture. On the STS side of ethnographic scholarly work, the use of the method is usually exemplified by the early laboratory studies of scientific knowledge in-the-making (Collins 1984; Latour and Woolgar 1986; Latour 1987), but the method still stands strong.

Based on these lessons in STS, I have worked according to the assumption that studying *practices* by means of observations often says more about the actual practices than if one were to *ask* the observed people in, for example, interviews, what they were doing or what they had previously said.

Sites 3 and 4: The local community and global policy

While the court procedure was somewhat formal and technical and took place in Stockholm, I also developed an interest in the locality where the spent nuclear fuel was to be disposed of. Hence, the third site of inquiry relates specifically to Östhammar, the municipality that hosts the Forsmark power plant and that has now been selected as the final candidate for final nuclear waste disposal. In the thesis, I wanted to convey at least a few insights into the issue of *siting* because it constitutes a central problem for many implementers. Moreover, Sweden is internationally known for its successful siting procedure, which prompted me to think about at least a few reasons for why this is.

While having a somewhat clear picture of the historical aspects of the Swedish siting procedure, I knew that SKB had developed a range of channels for disseminating 'information' between the industry and the local community. Since I already knew that the nuclear industry subsidiary SKB had produced several issues of the magazine *Lagerbladet*, which is devoted to addressing local everyday life in the municipality, I concluded that this material was worth approaching to learn more about the nature of the information and communication efforts. I think this material constitutes an important part of how certain siting actors go about producing what they call 'acceptance', or indeed 'consent'. I have summarized the extent of this material here:

Table 4.

Empirical material, Lagerbladet		
Lagerbladet Östhammar	Document analysis	***≈1000 pages***

Document study offers certain opportunities as well as limitations. In themselves, documents often remain without adequate context, rendering the social reasons for their existence unclear. Neither do they report the specifics of the social and technical *practices* that take place in their company, nor do they necessarily enlighten us about the broader implications they entail.

What they do offer, however, is a range of insights. Documents are important to consider because they determine what is 'true', define what themes are 'relevant', conclude what the correct answer is to a given question, intervene in controversies, and might even produce new controversies (Asdal and Reinertsen 2020, p. 13). Hence, the notion that documents merely provide *discursive* insight misses the point that documents may also be of more practical importance.

These insights into documents are also relevant to the fourth and final article, or site, which builds on policy documents produced by the NEA and IAEA. We chose these actors because they are internationally known and influential for a range of national NWM organizations. More importantly, since I had read a range of policy documents before the production of Study IV, I had noticed that that the NEA and IAEA had started treating *emotions* as an important issue in siting processes. Most notably, I had discovered that they now sought to place emotions on the *inside* of the public participation exercises. To me, this appeared to be an important shift from considering emotions as unrelated to the technical project of siting repositories, an understanding that had previously reigned in NWM. My co-author and I therefore wanted to more thoroughly explore how this new form of emotion management was seen by the core actors in the field.

Consequently, we identified a range of documents that more closely elaborate on how emotions were to be, and not to be, introduced into public participation in NWM. Below, I have compiled a list of the scope of these documents on which Study IV builds:

Table 5.

Empirical material, IAEA and NEA Policy			
IAEA	5 reports	Document analysis	***≈340 pages***
NEA	12 reports	Document analysis	***≈950 pages***
Total:	17 reports	Document analysis	***≈1300 pages***

In relation to the topic of emotions combined with NWM, I think our endeavour is somewhat novel, as is the finding that emotion management has become part of the repertoire of siting actors.

Analytical procedure, data analysis, and critique

The pros and cons of particular methods notwithstanding, I am sympathetic to the view that the analytical procedure is even more central than the methodological procedure. The analytical procedure imposed upon the methodology, together with the theoretical outlook, generates the most interesting results (which may vary substantially depending on the procedure). This simultaneously underlines the need to be clear about how the results were produced and achieved. Throughout the work on this thesis, I have employed a similar analytical procedure. In what follows, I explain and describe this analytical work.

So far, I have described my navigation through various sites of NWM, and about the extent and scope of the data. What remains to be discussed is how I have approached and analysed the data, so I will address the different methods employed in this thesis and the data that they have produced.

Working with data inevitably involves processes of interpretation by means of sensory impressions. It is often held that most research is to some degree 'abductive', that is, achieved by a particular mix of 'induction' and 'deduction'. Hence, one cannot be either 'truly' inductive or deductive, but one relies on a combination of the two. To me, the term 'abduction' used in this way is too unspecific: if all research is abductive, then the term contributes little to clarifying the differences between methodological–theoretical approaches and their underlying assumptions.

Rather, the task should be to describe and reflect on *how* one has been abductive, more specifically. Moreover, it is difficult to separate methodology from theory, and any radical separation between the two is probably false, as methodological prescriptions have theoretical implications, and vice versa. Thus, the best I can achieve, and the best I can provide the reader with, is an account of how I have worked according to this conviction – or assumption if you will.

Formally, I have employed a form of 'thematic coding' inspired by Foucauldian policy analysis (Bacchi 2012). I have divided the methodological process into three steps – or three phases of coding – that move from the very concrete to the more abstract. To say that they are temporally radically separated would be false, so the following account should be understood as a simplification of the practical process of analysis.

In the first round of coding, I typically developed codes that as *descriptively* as possible reflect the problem representations, the assumptions, and the ideas conveyed in the empirical material. I did so to produce a narrative that concisely captures the rationale of the material, asking what is *actually* being said in it. What do the actors hold as 'true'? What 'is the problem represented to be?' (Bacchi 2009). In this first step of coding, I sought to be deliberately uncritical and, in an intellectually honourable way, recapture the logic of the material that its producers – or the actors that figure in it – hopefully would find just, accurate, and fair.

In the second step of coding, I typically contemplated what is not *explicitly* stated or mentioned in the empirical material. This has entailed identifying the ideas and presuppositions that tacitly underpin the rationale of the material. In addition to reiterating that rationale, in this step I contemplated what the *consequences* would be if one stuck to the rationale of the material, that is, also contemplating what is *implied* by the ideas conveyed in the data. I did so according to Bacchi's (2009, p. xviii) view that materials 'necessarily contain implicit problem representations that demand scrutiny'. From the first step of descriptive coding, I then typically proceeded according to the theoretical–methodological principle that space needs to be created to interrogate and challenge representations of 'problems' that are judged to have deleterious consequences' (Bacchi 2009, p. 253). I understood this second step of coding as moving up a 'ladder of abstraction' and contemplated the *unspoken* positions and presuppositions contained in the material that underpinned the rationale uncovered in step one of the descriptive coding. This step also entailed identifying logical incoherence and internal contradictions in the material that cannot be identified merely using uncritical descriptive coding. While the first step of coding does not demand great critical ability, the second step of coding places greater demands on one's critical imagination.

In the third analytical step, I typically proceeded to more independently *challenging* the content of the material, that is, subjecting it to competing logics and rationales that more directly contradict the logic of the material. By asking questions such as 'How could [the] dominant problem representations [of the material] be disrupted?' (Bacchi 2009, p. 96), I sought to identify and advance alternative problem representations that produce new understandings of the meaning of the material.

However, while Bacchi offers tools for revealing the silences and underlying assumptions of documents, she does not promote any *specific* alternatives or 'standard' problem representations. Hence, what was initially a more inductive methodological exercise typically eventually became more deductive to move beyond the agnosticism of Bacchi's methodology. Once again, I understood this advance in coding to be constitutive of an additional move up the ladder of

abstraction. This final step is also what I considered to be the 'real' sociological scholarly work, that is, the identification and deployment of sociological concepts that as independently and accurately as possible provide richer understandings of the studied phenomenon than the material itself can produce if it is merely described or understood on its own terms, according to its own concepts.

In this final step, then, I did not work according to any methodological orthodoxy. Rather, I have been inspired by the view that any formal methodological remarks, suggestions, or 'rules' serve as mere points of departure, 'because that is the most that a formal methodology can provide' (Feenberg 2017, p. 61). Along these lines, I was also inspired by the view that 'there is no substitute for insight, which cannot be formalized' (Feenberg 2017, p. 61). It is, however, difficult to account for exactly what constitutes 'insight', and it would be somewhat presumptuous to claim that the thesis does just that. It is for the reader to decide whether I have succeeded in this final stage of analysis. In relation to this, it is important to point out that seminars, reviewers' comments, and so forth have all collectively contribute to enhancing the insights. For this thesis, this essentially collective task has truly improved the quality of the studies.

Nevertheless, I have been inspired by what Marcuse (2002) has called 'negative thinking' – simply stated, critically imagining what could be, but is not. The analytical implication of my 'negative thinking' is a defence of *critique*. Critique is the means by which my *analytical* endeavours can be justified. As I think is shown in the constituent studies of this thesis, during my analytical work I have come to identify the vast distance between 'that which is' and 'that which ought to be'.

In sum, this process more precisely describes my understanding of 'abduction', that is, a move from inductive coding (to the extent that induction is even possible) in step 1 to a more deductive phase in later stages of coding when sociological theory is 'tested' against the realities of the empirical material. In the final stage of analysis, I have been much more concerned with sociological theory and the extent to which the material 'fits' various sociological postulations, and vice versa.

Reflections on methodological and analytical limitations

The results of this thesis are conditioned by how I selected methods and performed my analytical procedures. From what I have laid out above, some reflections on limitations are in order. For example, what might have further enriched this thesis is arguably interviews with

laypeople, that is, those actors whose understandings one would expect to diverge the most (but not necessarily) from technically rational understandings of NWM. Such interviews would potentially shed more light on the rationalities that underpin objections to more hegemonic forms of rationality in NWM. Something similar can be said about interviewing experts. Possibly, such interviews could shed light on the 'glitches' in technical rationality that are otherwise absent in arenas where experts are expected to speak with certainty and act with authority. What I have conceptualized as technical rationality might have appeared less pervasive had such materials been included.

I thus recognize that it is possible that deploying other methods could have produced different results. It is important to recognize that the same is true for how I selected the sites of inquiry. For example, the Land and Environmental Court and Modern2020 constitute delimited arenas, both geographically and temporally. Even though making observations at these sites was a productive way of learning more about them and what happened there, I think it is true that observations at other sites would likely yield a different type of data. In some aspects, such data could be richer. As a concrete example, participant observation in Östhammar (or other 'nuclear communities') would potentially more clearly capture the *relationships* between industry and local community, and better explain the degree to which subjects contest, resist, agree upon, and respond to the information campaigns and consent-building attempts described in Study III. As stated in several of the compiled studies, more research into these aspects would generate a deeper understanding of the problematics of NWM.

Hence, I do not understand my choices of methods and analytical procedures as the final word in studies of NWM. I instead consider them to be indicative of a need to further pursue the problematics in NWM, such as the examples cited above. Greater methodological and theoretical diversity in such a project, if one agrees that it is worth pursuing, would therefore be both advantageous and welcome.

Ethical considerations

Overall, it is my understanding that there are no *major* ethical issues associated with my research. My participation in Modern2020 appears unproblematic, from an ethical point of view: I was enrolled in the project specifically for the purpose of conducting research, and was integrated into the project with the very *invitation* to gather data. I have considered this fact as constitutive of the principle of 'informed consent'.

Similarly, the court procedure on which one of the articles is based was also a public event, and I contacted the judge before the proceedings, explained the reasons for my participation, and asked whether I was allowed to record sessions. According to Swedish law, one can record audio, but not video, in session. As the proceedings were public events that encouraged broad participation, it appeared unreasonable to place any far-reaching constraints upon their scholarly scrutiny. Furthermore, the proceedings' minutes, the court's formal decision, and the plaintiff's correspondence all fall under 'the principle of openness' (*offentlighetsprincipen*), which means that the material is available to anyone, and there is no quid pro quo (Tryckfrihetsförordning 1949, p. 105, second chapter).

The ethical aspects of the document analyses presented in this thesis can be evaluated in a similar way. The material in Study III was derived from a magazine that anyone can subscribe to for free (e.g., Lagerbladet Oskarshamn 2016), and it is available in digitized form online for anyone to download. The material for Study IV was derived from public policy documents from the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), all of which are publicly available.

It is thus my view and understanding that the studies compiled in this thesis can be placed in a category of research that, according to the Swedish Research Council, does *not* require closer (that is, formal and legal) ethical scrutiny, according to Swedish law (SFS 2003:460; Swedish Research Council 2017, p. 15).

To be clear, even though the law states that closer ethical scrutiny is not necessary for the type of material employed in this thesis (SFS 2003:460), this does not mean that I should refrain from ethical *reflection* (Swedish Research Council 2017, p. 15). Despite my assessment that there are no *major* ethical issues, there are still some ethical considerations.

Although I have used publicly available material, I have placed this content into a new scholarly and social context. To be sure, the intended meaning of statements or phrases in, for example, policy and magazine material may be lost in the translation from original text to scientific article; actors' statements have admittedly ended up in a context they perhaps did not intend for them. For instance, in Study II-III, I occasionally quote the words of citizens to confirm the validity of my argument. This *might* be problematic because the citizens quoted simply might not agree with me. At the same time, however, it is difficult to see a concrete solution to this potential problem.

The closest thing to a solution that I can foresee is that of explicit scholarly reflection. While a discussion of ethics could be understood as a formality, and while one can restrict it to relating solely to the matter of following the guidelines of actors such as the Swedish Research Council, it

is possible to broaden such a discussion. To exemplify, I refer to my previous methodological and theoretical discussions, which have ethical implications that I will briefly invoke in some final ethical remarks. This is because, although ethics are often reduced to a matter of 'right' or 'wrong', I consider it equally important to be transparent about how one has conducted research, why one has chosen particular theoretical frameworks, how alternative research paths could have been explored, and so forth. I have considered this mode of doing research as close to what Alvesson and Sköldberg (2009, p. 271) have called 'reflexive interpretation'. By this I mean that I have sought to expose the 'open play across various levels of interpretation' (Alvesson and Sköldberg 2009, p. 271). According to my understanding of reflexive interpretation, its ideal of doing research posits that one cannot make clear distinctions between 'method' and 'theory' – to cite one example – as the two are inherently intertwined. Instead of seeking to backtrack and present my research as having emerged linearly (from research question, to method, to theory, etc.), I have sought to make it clear that the different parts of the research have implications for one another. As such, while a thesis – this one included – is presented in an orderly fashion, the actual research work is a lot messier. I have sought to describe this messy process for the sake of both transparency and reflexivity. Whether I have succeeded is for the reader to decide, but the principle of reflexive interpretation I have considered to be an (informal) ethical procedure in and of itself, that is, beyond any formal guidelines that seek to govern research.

Study I

Lagerlöf, H., Sundqvist, G., & Bergmans, A. (2022) Striving for technical consensus by agreeing to disagree: The case of monitoring underground nuclear waste disposal facilities. *Journal of Risk Research*, 25(5), 666–679.

In this study, we investigate how an international technological EU project sought to integrate new monitoring technologies into existing NWM programmes. We note that many existing national waste management programmes honour so-called passive safety, that is, the idea that repositories should require no *active* measures to uphold safety once implemented. Safety is to be provided a priori.

In recent decades, however, there have been increasing demands for safety to be enhanced by more *active* measures. The advancement of various forms of technological monitoring devices – such as sensors that can be emplaced deep underground – has sparked interest in whether it is possible to enhance safety during, and even after, the closure of repositories. In essence, because of their divergent underlying understandings of how safety can be achieved, passive and active measures are potentially in conflict with each other. Can the two somehow be reconciled, or are they mutually exclusive?

The task of resolving this potential conflict was delegated by the EC to a project called Modern2020. In addition to navigating the potential contradiction between active and passive safety, the project was simultaneously expected to produce technical consensus among its many international members. The authors of this paper participated in this project, and the empirical material that the study is based on was derived from participatory observation and document analysis. We take special interest in analysing how the project sought to navigate active and passive safety measures and other contradictory aspects that arose during the project.

Empirically, we highlight that active and passive safety measures are treated somewhat differently in different countries. This means that Modern2020 faced the additional difficulty of reconciling discrepancies among national programmes, which to different degrees demanded passive safety measures. By presenting the political and technical contexts of two national programmes – the Swedish and French – we show that the political and legislative preconditions

for monitoring differed substantially between the countries. While certain forms of monitoring were *required* in France, the same forms of monitoring were *prohibited* in Sweden.

To add to the complexity, we also note that projects instigated by the EC are obliged to uphold a range of values. Modern2020 was thus obliged to also take into account the core values of the EU's visions for energy policy, market expansion, and so forth. The project thereby faced the EU's expectation to honour certain (political) values by producing consensus amid the simultaneous turmoil of divergent national trajectories. Essentially, the expectation to contribute to the EU's 'harmonization' of technical standards while simultaneously facing a not entirely harmonized world was the situation Modern2020 faced.

To make sense of this situation theoretically, we turn to STS. In our theoretical discussion, we note that sociotechnical arrangements seeking to produce consensus are understood differently by different theories in STS. Some scholars argue that ambitions of consensus are *coercive* in that they subordinate 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, downplaying processes of coercion and exclusion, and instead emphasizing 'multiplicity'. In this article, we combine both these seemingly contradictory insights to understand the outcome of the Modern2020 project.

In our analysis, we show how the turmoil Modern2020 faced was eventually reconciled by 'agreeing to disagree'. By producing consensus at the level of technical protocols that allowed a certain degree of flexibility for the existing national programmes, both the political values of European harmonization ideals 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 were constituted by the naturalization of EU policy, but that such coercive efforts still left some room for diversity, that is, flexibility for the national programmes. The work in Modern2020 was finally represented as technical consensus, yet the project refrained from intervening in locked-in national NWM trajectories.

In turn, this meant that the project managed to circumvent any conflict between activity and passivity, because the 'agree-to-disagree' stance simultaneously allowed the respective national programmes to pursue whatever safety measures they deemed suitable. This means that Modern2020's technical consensus conveyed at the end of the project still accommodated the tension between activity and passivity. However, its technical protocols were designed in such a way that they, first, honoured the harmonization demands of the EU and, second, did not interfere with locked-in trajectories. Hence, the underlying conflicts and inconsistencies that the

project had in fact navigated, and that had guided its tasks from the outset, were in the end concealed by the technical protocols.

In this article, I have, together with my co-authors, gathered data from Modern2020's formal and informal meetings and internal databases. Parts of the analysis also build on data that I gathered individually without the participation of the co-authors. The analytical work emerged primarily through discussions and cooperation between me and Göran Sundqvist, but with substantial insights from Anne Bergman. During the submission process, Göran Sundqvist was initially granted first authorship, but I took over the role of first author during the revision process. This means that I had the primary responsibility to communicate with the editorial office after the first editorial decision, to coordinate the work efforts between co-authors, and for primary drafting.

Study II

Lagerlöf, H. (2023) Swedish nuclear waste management as an inert controversy: Using critical constructivism to understand cold technological conflict. Accepted in *Science as Culture.*

In this study, I analyse how an industry application to build a repository for nuclear waste was scrutinized in a Swedish court. There, a copper corrosion controversy became central, because regulation requires that the copper canisters that will encapsulate waste should be safe for 100,000 years. By using *facts*, counter-experts and environmental NGOs convinced the court of the uncertainty engendered by the corrosion. The parties engaged in the controversy were not explicitly engaged in 'broader' issues such as equity and environmental justice; rather, it was the strictly scientific aspects of the application that attracted attention and created contention.

I suggest that the nature of the controversy makes germane a particular theoretical tension in STS. This tension consists of my observation that research within the field of STS is ambivalent about the usefulness of studying controversies that remain, rhetorically and procedurally, technical despite simultaneous expert and lay participation. Contemporary STS tends to assign priority to 'overflowing' controversies, that is, controversies during which lay actors challenge experts' technical frameworks by explicating their broader implications. This misses the significance of controversies where the broader implications remain stubbornly unspoken. The present controversy did not overflow, which I argue actualizes the above problem. Simultaneously, however, the controversy presents an opportunity to elaborate theoretically on what I call 'inert' controversies, that is, controversies that do not overflow and that are 'cold'.

With a few caveats, I propose that Andrew Feenberg's critical constructivism – an alloy of STS and the Frankfurt School – can contribute to this. A first contribution is its ability to explain *why* controversies remain inert. A second contribution is its capacity to explicate the broader implicit issues, independently identifying what is at stake, regardless of the actions and statements of the actors. To arrive at these contributions, however, I argue that critical constructivism needs to emphasize its critical heritage. This is because, like many contemporary studies in STS, critical constructivism has increasingly come to elaborate on *change* at the expense of Frankfurt School-style critique of the status quo. By invoking the longstanding STS idea of 'structural closure' – the proposition that controversies can be closed by hegemonic structures – inert controversies can be addressed by critical constructivism, contributing to the explanatory potential of a broader set of controversies in STS. Mainly, I elaborate on how 'technical

rationality' – a dominant form of rationality in modern societies – can be used as a theoretical concept to understand why controversies remain inert.

Methodologically, I relied on participant observation in the court, but I also provide a brief history of Swedish NWM to contextualize the subsequent controversy. My core insight from this section is that important actors in the field have successfully managed to frame issues of nuclear waste as radically divorced from, for instance, energy policy and any other contentious issue. Instead, NWM has been framed as a strictly technical issue that requires technical know-how. As such, there has emerged a very narrow window for critique: to appear 'rational', even lay actors need to engage in technical issues.

Against this background, the subsequent happenings in court appear less surprising. By relying on my observations, I highlight a process essentially preoccupied with the *scientific* aspects of corrosion. Whereas nuclear waste and NWM arguably touch on a range of aspects that lay actors could be expected to bring up, these were conspicuous by their absence. Instead, the court process exacerbated the technical preoccupation. In the end, the court concluded that the uncertainty engendered by the corrosion warranted a halt in the application process. While this was conceived of as a victory in the environmental movement, I propose that the outcome represents a victory for those who have an interest in maintaining that NWM is a strictly technical issue.

In conclusion, I argue that the events in court were the result of a technically rational culture that has evolved over time. Understanding the conditions of the controversy requires contemplating what was not *immediately* evident in the proceedings, that is, the structures conditioning the scope of the conflict. From these assertions, an additional proposition I make is that that *critique* can be successfully deployed in controversies in which there are few or no overflows. While contemporary STS typically refrains from analysing controversies in which lay actors do not challenge the narrow technical frameworks of experts, critical constructivism can contribute by invoking a broader set of controversies to be considered by scholars in the field.

Study III

Lagerlöf, H. (2023) Consenting publics: Fair nuclear waste repository siting? Published online ahead of print in *Environmental Politics*, DOI:10.1080/09644016.2023.2172867

Technical experts in the field of NWM often claim that they have a safe technology for disposing of spent nuclear fuel. Geological disposal – the technology of emplacing spent nuclear fuel and high-level nuclear waste deep underground in canisters – is generally proposed as *the* solution to the waste problem. Technical consensus aside, it has still proven difficult to *site* the geological disposal facilities, or repositories. This is because there is typically local resistance and opposition at sites proposed as hosts for repositories. This has taught powerful siting actors that publics cannot be circumvented in siting processes. Siting actors therefore now seek to *include* publics in siting processes to get their 'acceptance' before implementation.

Such processes, however, have been proven by previous research to be burdened by asymmetric power relationships between implementers and local publics. Often, the implementer controls and dominates the participatory arrangements that are meant to facilitate the 'meaningful participation' of publics. In light of this experience, research on repository siting has increasingly proposed that the dominance of key actors in siting processes should be counterbalanced by the greater inclusion of disadvantaged local publics and greater implementer consideration of the public interest. Often, public *consent* is in this context represented as a guarantee of 'fairness' in siting processes.

In this study, I problematize this notion in previous research by showing how consent is pursued by powerful actors, and how the pursuit of consent has progressed in Sweden. I argue that Sweden is an important case to study, because the Swedish NWM programme is internationally held up as a 'role model': other countries struggling to site their repositories turn to Sweden to learn about the democratic way of doing so. Swedish progress thus has international implications. In the municipality of Östhammar – the proposed site of a repository for spent nuclear fuel – there is allegedly broad support of the nuclear industry's site investigations and the public is said to consent to the future construction of a facility for spent nuclear fuel.

However, previous research has yet to demonstrate and understand in greater detail *how* the nuclear industry in Sweden has pursued the consent of the local community of Östhammar. What is the nature of the industry's communication work in the municipality? To better understand Sweden as a role model and the type of consent that the industry has pursued, I draw

on the nuclear industry's written material distributed to citizens in the repository candidate community of Östhammar. More specifically, this material constitutes *Lagerbladet*, a magazine produced by the nuclear industry with local citizens as the intended audience.

In analysing this material, I first situate it in its broader context. I show that Swedish municipalities' right of veto in siting inquiries along with public opposition have resulted in a creative industrial siting strategy that has abandoned overt coercion; rather, siting actors now aim to create consent by *attending to* local interests and culture. Whereas this endeavour corresponds to the call of much previous research, for implementers to take into consideration the interests of publics, potentially producing consent, I instead propose that the communication strategies highlight the problems of consent-building.

I base this argument on theoretical concepts that understand the production of consent as a specific form of power. Rather than being understood as an end goal, consent-building is from this perspective seen as a tactic deployed by powerful actors to *forestall* opposition, that is, avoid conflict. In light of these discussions, the consent-building strategy of the Swedish nuclear industry appears less ideal. Instead of concluding that Sweden has progressed in a particularly democratic way, I propose that the Swedish nuclear industry has drawn on the 'third dimension of power' to achieve its goals. This means that the industry is imposing on publics particular – and biased – problem representations and reductionist ideas. This entails blurring the distance between industry and the local public, representing the interests of industry and the local public as essentially aligned and defining what is a 'good' and 'bad' citizen, to cite but two examples. The industry's consent-building strategy is thus laden with biases that paint a rather reductionist image of the problems that repository siting entails.

In light of these results, I conclude that the inclusion of local interests is no panacea for siting 'fairness' and that siting processes in NWM are inevitably unfair. Instead of lingering in an attempt to facilitate better participation, as much research has done, I propose new ways of studying siting controversies in NWM. This new route for research is mainly informed by theory and previous studies in the field of social movements and the control of environmental activism. As such, I propose that the study of consent, quiescence, and opposition, even outside the formal arrangements of public participation, should be conducted to better understand the nature of the consent-based siting strategies that have emerged, and that are continuously being refined.

Study IV

Lagerlöf, H., & Pettersson, J. (2022) Aligning Subjective and Objective 'Truth' in Nuclear Waste Management: On the New Role of Emotions in Contemporary Repository Siting Policy. To be resubmitted to *Emotions and Society*.

What remains after nuclear power production – spent nuclear fuel and high-level waste – is seen by the vast majority of technical experts as best handled by means of 'geological disposal' – that is, storage deep in bedrock at a supposedly safe distance from the biosphere. While safe geological disposal concepts, also called repositories, were presented as within reach of modern science and technology already almost half a century ago, the *siting* of disposal facilities has proven more difficult. With a few exceptions in contemporary Scandinavia, local publics typically resist siting attempts.

Previous research has shown that siting projects have been characterized by pervasive technocracy: the siting of repositories has been represented by responsible actors as relying on *technical* criteria such as bedrock conditions. Implementers did not at first take into consideration either the wants and wishes of local publics or their emotional needs. Scientific 'truth' would determine repository location. Hence, emotions have historically been rejected as irrelevant, or even as 'irrational distractions' standing in the way of repository implementation.

However, siting procedures have evolved over recent decades. Consequently, much research now focuses on novel forms of NWM engagement in local communities and deliberations with publics, that is, aspects beyond strictly technical criteria. Even though technocracy has not simply vanished, siting processes are now understood – by implementers and scholars alike – as depending on emotions such as mutual trust.

In this article, we propose that the shift from siting procedures that refer to scientific 'truth' devoid of emotion to more interactive forms of participation that also take into consideration 'softer' aspects of siting implies an evolved relationship between rationality and emotion. This issue is one of the theoretical specialties of the sociology of emotions. Crucially, emotions are now granted *explicit* standing in NWM, in noteworthy contrast to historical approaches. It remains unclear, however, how emotions are to be handled and incorporated into siting procedures, more precisely.

To start learning more, we analyse contemporary implementer policies that elaborate more specifically on the new role of emotions in NWM. Theoretically, because rationality and emotions are inseparable, we consider it our central task to examine the specific ways in which emotions and rationality are interwoven, according to implementers. By exploring what emotions

are attributed to the publics by implementers, we analyse what forms of rationality and emotion are held as ideal. What emotions are granted importance in the implementer policy 'truth regime'? What emotions are represented as rational and, indeed, irrational? Finally, what are the implications of the relationship between emotions and rationality that emerges in the material?

In our analysis, we explore and critically discuss contemporary siting policy as a case of the 'discursive projection' of publics' emotions – that is, not as a 'true' account of publics' emotions but rather as indicative of implementers' understanding of publics' emotions, of what is and is not rational. In the analysis, we understand policy as an 'emotion regime' that establishes what feelings are and are not compatible with the 'truth' that repositories for spent nuclear fuel constitute the best solution to the waste problem. Understanding the relationship between emotions and reason from an emotion-sociological perspective, we show how the emotion regime in policy has been transformed from being a clear-cut case of a conventional approach that understands rationality and emotion as inherently incompatible, to an at first glance more radical understanding of the relationship between rationality and emotion. The analysis identifies what emotions are described as a threat to reason and what emotions are described as aiding implementers' reason and rationality, and hence which emotions are idealized – and rejected.

We conclude that we cannot understand the new focus on emotions in NWM as unconditional. While the new focus might at first glance appear radical, when studied more closely, it perpetuates many of the pre-existing technocratic ideas in NWM criticized by previous research. The shift from a conventional view of the relationship between rationality and emotions to what we have called a more 'critical' view should thus not be exaggerated. In reality, the conventional view still holds in many regards. Importantly, the focus on emotions constitutes an elaborate way to facilitate implementation.

The work on this article commenced on my initiative. Together with my co-author Jane Pettersson, we jointly selected the relevant empirical material. I had the primary writing responsibility and coordinated the writing efforts between the two of us. The theoretical work emerged through discussions between us; the same was true of the analytical work. As corresponding author, I have appraised and responded to the remarks from the editorial team, while both of us worked on revising the paper in a way similar to what is described above.

7 Conclusions and discussion

I started this dissertation by asserting that contemporary NWM – sometimes invoking 'the Swedish model of NWM' as inspiration – is laden with certain contradictions and tensions. First, I established that nuclear waste constitutes a 'wicked problem' (Rittel and Webber 1973), that is, a problem to which there is only a set of suboptimal 'solutions' to choose from. Second, I also held that NWM has broader implications rarely acknowledged in the NWM field. I illustrated this by maintaining that while NWM presents itself as radically divorced from the politics of nuclear power production, it simultaneously serves as a cornerstone of its legitimization (Elam et al. 2010). Despite these tensions, NWM now claims that 'it is time to proceed' because any 'remaining challenges' are understood as having finally been overcome (IDG-TP 2015). Having identified these tensions and contradictions, as well as NWM's understanding of them as overcome, I formulated the central objective of the dissertation as accounting for how NWM can progress under these circumstances, that is, *in spite of* the broader implications and wicked problems described above.

From the perspectives I have employed and my interpretations of the empirical material, the progress achieved in NWM cannot primarily be understood as the result of an open, transparent, and democratic process, which is an otherwise prevalent understanding (cf. Dawson and Darst 2006). Instead, I have sought to explain this progress by showing NWM's ability (sometimes deliberately, sometimes not) to exclude and/or forestall certain forms of critique, grievance, and opposition that could bring to the fore NWM's wicked problems and broader implications, had they been considered. Thus, on an aggregate level, the studies together imply that for NWM to successfully implement geological disposal, that is, to progress from stalemate while simultaneously appearing democratic and open, it needs to exclude or suppress reasonable objections that would potentially challenge NWM's biases and expose its historical contingencies and preconditions.

The above provides part of the short answer to the question of how NWM, despite its broader function in a system of organizations and technologies, maintains its separation from the other realms in this system. The historical contextualization that I initially provided served to situate NWM in its broader context, but also served to illustrate the historical contingencies of contemporary concerns in the field. Hence, an additional part of the answer as to how NWM has successfully naturalized itself as an independent entity in a broader system relates to how its historical roots have been forgotten. According to my understanding, then, reification – that is,

the process by which both humans' and objects' historical contingencies are forgotten – is at least partly what makes it possible to neglect NWM's function in a broader system of markets, technologies, and administrations (cf. Cassegård 2021).

Work also needs to be carried out to maintain the separation. Hence, I also asked how the inherent problems, ambiguities, and broader implications were rhetorically and practically handled and addressed in NWM. As shown in more detail in the individual studies, the progress of geological disposal is coupled with the concealment of the social interests that underpin the urge to act to implement it. According to my results, with reference to *technical* consensus, NWM enables the advancement of particular *social* interests. According to these particular results, the problems, ambiguities, and broader implications were handled in NWM by the production of technical protocols. The protocols, in turn, navigate tensions between a selection of social interests. Hence, NWM does not 'erase' perpetual problems and contradictions; instead, with reference to technological rigour and technical consensus, it circumvents them (Study I).

Additional examples can be found in the individual studies. For instance, the idea that geological disposal facilities can be sited democratically and 'fairly' is perpetuated by powerful actors with superior means to advance their social interests and naturalize their reductionist depictions of, and reified forms of, NWM. Consequently, competing interests that do not serve the goal of implementation are marginalized and critical remarks are categorized as irrational and/or as destructive, to the degree that they are explicitly considered at all (studies III and IV).

By promoting this understanding of opposition, and by employing tactics to forestall resistance, it is possible for NWM to avoid elaborating on its broader implications, and on its relationship to, for example, nuclear power. I described the clearest example of this in Study III. By constructing *consent* as the 'reasonable' stance for citizens to adopt, and by understanding opposition as rooted in ignorance – or indeed as comparable to petty quarrelling – dissent and critique can be suppressed and dismissed.

I understood this power dynamic as having emerged from the nuclear industry's longstanding experience of local opposition, which in turn has prompted siting actors to develop increasingly creative siting strategies. From more overt forms of coercion in the siting of repositories for spent nuclear fuel and high-level waste in the past, the failure of such efforts has led to more elaborate forms of wielding power. As I have suggested, ideological power is now more widely exercised to forestall opposition. By securing the willing consent of local publics in nuclear communities, the prospect of progress is improved. However, this is not a development that has led to 'fairer' siting processes. This is primarily because actors' abilities to naturalize their

ideologically laden conception of what is at stake, and what is the problem, are conditioned by the forms of power they possess, and power is distributed unequally (cf. Lukes 2021).

This form of domination notwithstanding, I do not wish to paint a picture in which NWM appears to be entirely autocratic; there are of course actors with certain objections, and NWM has in different ways responded to them. So, are the assertions of progress contested? If so, how? What forms of critique are being articulated? By whom? Relating to the rejection of political critique as irrational and dissent as unreasonable is the simultaneous tendency in NWM for opposition often to be funnelled through *technical* endeavours. Hence, technical debates sometimes become proxies for political conflict. The political critique and the grievances that still do exist – the suppression described above notwithstanding – thus take predominantly *technical* forms, at least according to my results.

In the prevailing culture of NWM, among the few areas in which critique is still seen as legitimate is in strictly technical domains. Scrutiny of scientific–technical detail is recognized as a viable enterprise because of its association with technical rationality, thus taking precedence over other forms of critical procedures based on, for example, lived experience of technology or various ethical concerns.

The implication is that when critique is based on political concerns – although emerging in the guise of technical objections – it is injured by the NWM technical paradigm because technical and scientific knowledge trumps other forms of knowledge, benefitting those with the appropriate technical know-how. Expert knowledge prevails over lay knowledge; actors who speak technical experts' esoteric language are also more likely to realize their *social* interests. This is close to what Feenberg (2017) would call 'formal bias', that is, power relationships that render, not necessarily intentionally, social asymmetries and widely differing opportunities to influence, for example, technology.

Additionally, the social interests that potentially underpin the positions taken in the *scientific* and *technical* controversies remain concealed in a system that celebrates objectivity. Ironically, the objective scientific scrutiny of copper corrosion described in Study II rendered subjective social interests invisible. Still, such social interests possibly were in play because several of the most influential actors engaged in the scientific controversy had economic stakes in keeping the spent nuclear fuel above ground.

Some of the above examples overlap the answers to the question of how nuclear waste managers address, manage, and respond to social and technical critique of, and opposition to, NWM governance. Nevertheless, this dissertation illustrates how critique of NWM is rejected by means of several different tactics. As a further example, the observation that an objectivist

tendency reigns in NWM is reinforced by the fact that certain emotional concerns about nuclear power and nuclear waste are conceptualized as wholly 'unscientific', that is, as illegitimate in the face of NWM technical rationality. While NWM has abandoned its 'old' emotion regime that disallowed *any* form of emotion, perpetuating the false divide between reason and emotion (Barbalet 2001, 2002), and while NWM now has granted importance to a greater range of emotions, the new emotion regime (Reddy 2001) still serves to forestall critique and advocate the incorporation only of emotions that *do not contradict* the social interests of those who seek to implement repositories (cf. Mussell 2017). To once again speak in terms of progress, even the prescribed emotions in NWM are conditional (Study IV).

Taken together, the social and technical phenomena examined by the individual studies that characterize NWM, but that are not acknowledged by NWM itself, all exemplify what the cost of progress in the field might be, both theoretically and practically. To be sure, these insights and conclusions are the product of certain theoretical points of departure. I have understood the above findings as constitutive of a process by which both subjects and objects in NWM are reified. By highlighting the ideas advanced by – and rooted in – technical rationality (Feenberg 2017), one ambition of mine was to contribute to the dereification of the reified forms imposed upon objects and subjects in NWM. From my perspective, holding that progress is conditional in particular ways contributes at least in part to that.

I have argued that the perspectives proposed in this thesis diverge from those of much previous research into NWM. Theoretically, I have understood the naturalization of NWM's reductionist ideas as legitimized by – and rooted in – a form of technical rationality (Feenberg 2017) that despite its formal biases has successfully promoted itself as 'democratic', 'fair', and symmetrical in its power relations. I have argued that rationality as an overarching concept, together with other neighbouring concepts in critical constructivism, can successfully aid in formulating a critique that is arguably much needed, in both STS and the public debate. Hence, rather than using NWM as an example illustrating how the *potential* of democratic procedures could be discussed (cf. Callon et al. 2009), and rather than implying that the democratic deficits can be remedied by various deliberative processes (Krütli et al. 2012), public interventions, or revealing the 'sociotechnical challenges' of NWM, I have argued that it makes more sense to make clear the *inevitable* democratic deficits produced by uncontrollable and *irreversible* technological by-products of technology, in this case nuclear power.

Even though much research has already critiqued NWM for being technocratic, my conclusions are different in that I have highlighted the irreversible damage inflicted by nuclear waste on the prospects for change. According to my view, far-reaching democratic control over

NWM is particularly hopeless because the material properties of nuclear waste inevitably limit the actions available to those seeking to control it.

However, this does not mean that NWM should be ejected from discussions of the potential for democratizing technology, or excluded from the 'sociotechnical' debate. On the contrary, other fields that hold greater prospects for change have many things to learn from the irreconcilable issues generated by technical rationality in NWM. The 'dystopic' image of NWM that emerges from my analyses should not be understood as defeatist. Rather, I consider NWM a case in point for a range of different problems – such as technological hubris – in modern societies. NWM somewhat neatly illustrates rather universal problems associated with the relationship between democracy, science, technology, and society; today's problem with nuclear waste is indeed the product of the technological hubris of yesterday. Arguably, something similar is *currently* happening in relation to climate change: our actions today are undertaken with reference to not-yet-existing technologies that will remedy emissions tomorrow. There is a good chance that we will experience irreversible consequences that have far-reaching implications for generations to come, and with little prospects for governing them. NWM illustrates the shortcomings of a rationality that understands itself as technologically omnipotent.

Thus, a central normative message of this thesis is that if democratic control over technology is the desired goal, then one must confront the hubris of seeking to dominate nature, a hubris central to the NWM rationality and that exists elsewhere as well. For NWM, it is already too late to achieve any far-reaching change, but other areas still have the chance. This is a much more pessimistic message about the prospects for achieving democratic control over NWM than that of most previous research I have encountered, yet I hope I have demonstrated that it is a viable one.

The form of 'inertia' in NWM that I describe in Study II – and that I also bear in mind in relation to the remaining studies – has a few theoretical implications for STS that I have sought to address. My main claim is that the predominant materialisms in STS tend to prioritize the study of volatility, heterogeneity, and multiplicity, while social constructivism in STS has abandoned overarching concepts. Applying critical constructivism, STS has come to focus mainly on how technologies are contested *within* the technosystem, not on how the status quo of this system persists. Prevailing perspectives in STS, I have argued, render situations that lack grievances inaccessible to methodologies that primarily attend to explicit and volatile conflict and differences of opinion. Moreover, to prioritize the study of volatile, heterogeneous situations (as much contemporary STS does) might lead to downplaying and making invisible those situations that *do not* arise because of what I have conceptualized as structural preconditions. This is not an

entirely theoretical exercise; I simply think that inertia is a far more prevalent characteristic of much NWM than is volatility, empirically speaking – at least in my examples. It is not that there is no heterogeneity; there is, but it does not reveal itself to any substantial degree.

While critical constructivism – the general framework in which I situated this thesis – brings to STS a form of structural thinking that I suggest is otherwise de-emphasized, I have not been entirely uncritical of critical constructivism's conceptualizations of technological change. As I demonstrate in Study II, the reality of NWM lends more authority to critical constructivism's critical legacy, that is, its Frankfurt School influences, than to its ANT-inspired thoughts on the nature of technical controversies. Once again, the general lack of far-reaching public critique that, at least in the studies compiled in this thesis, characterizes the sites studied calls for concepts that can explain *lack* of grievances and the domination that is required to keep it that way.

This thesis is a call to increase theoretical diversity in studies of NWM, and the above assertions have been merely one way of doing so. As an overall contribution, I have sought to demonstrate the feasibility of deploying divergent theoretical concepts to improve knowledge of the nature of the ideas and practices of NWM. For the field dedicated specifically to empirical studies of NWM, it has been my intention to diverge from previously proposed research paths by formulating an alternative path. By borrowing Burawoy's distinction between different forms of sociology, I propose that his categories of 'critical' and 'professional' research could serve both as analytical tools for navigating NWM research, and as inspirations for future research on NWM. To these categories of research, I hope to have contributed. However, while I hope that the reader agrees regarding these contributions, I simultaneously recognize the limitations of my work. As I write in the individual studies, they do not claim to be exhaustive, and they all testify to the possibility of being elaborated on by means of additional research. The studies compiled in this thesis should be understood as a starting point for further contemplation, rather than the final say.

More concretely, I think that one avenue to pursue in studies of NWM – by means of a greater diversity of methods than I have used – is to examine how the production of consent is realized in practice, as well as the ways in which it is resisted. I would like to see studies in a range of countries and (nuclear) communities, preferably with occasional comparative features (see studies I and II). What is further implied by my project – if one accepts the assertion that NWM constitutes a wicked problem – is the need to elaborate on more biases that *inevitably* emerge as NWM progresses. Such biases can be studied in a variety of ways, beyond the scope of this project.

Finally, I will leave the intra-scientific problematics and elaborate on the broader societal implications. How is one to understand the new context of energy policy that I described in the introductory parts, given my results? Most centrally, the results of this thesis call into question the assertion that nuclear power's waste problem has been remedied through the deployment of science, technology, and democracy. This has implications for the broader societal context. The results of this dissertation show that the utilization of nuclear power is not without economic or sociotechnical cost, because even the most relied-on democratic model of NWM is burdened with constraints, as illustrated by the individual studies.

Any call for nuclear power has consequences: it clearly brings about what Feenberg has called 'causal feedback', but that could also be called 'externalities' or 'unintended side effects'. As I have argued, the above assertions provide a basis for accusing the nuclear technology discourse of being ambiguous about its representations of the prospects for human action and change. At its core, this discourse advances the oxymoron that we are at once *slaves* to certain forces of nature (and indeed markets) that 'demand' the continuation of increasing energy production, yet masters of other natural forces because we can safely contain nuclear waste by means of science and technology for 100,000 years to come. That is, we can dominate nature without repercussions. We thus appear defeatist in the face of markets and energy demands but exhibit hubris in the management of nuclear waste. As it appears, this oxymoron serves particular social interests. In an age when nuclear power is on the rise, it is noteworthy that, while NWM is represented as democratic and transparent, the issue of nuclear new build is represented as inevitable; from the perspective of this thesis, the situation is precisely the other way around.

8 Sammanfattning på svenska (summary in Swedish)

Introduktion

En lång rad stater och företag har använt kärnkraft i decennier och därmed demonstrerat att det är möjligt att både utvinna uran ur marken och att sedan använda uranet för att producera elektricitet i reaktorer. Emellertid har det avfall som uppstår efter att elektriciteten producerats lagrats provisoriskt i väntan på en ”säker lösning”. I skrivande stund har inget land implementerat en sådan lösning även om ett fåtal är på god väg.

Kärnavfall är både farligt och kontroversiellt vilket för med sig en rad problem, både tekniska och sociala. Trots detta är det en vanlig uppfattning bland ledande aktörer inom kärnavfallshanteringsområdet att kvarvarande problem nu är lösta och att det är dags att implementera tillgängliga och säkra lösningar.

I denna avhandling problematiserar jag denna uppfattning. Genom att i stället förstå kärnavfallshantering som ett ”lömskt problem” (wicked problem), och med det menar jag ett problem som inte kan lösas (man kan bara välja bland en rad suboptimala lösningar för att hantera det), så anlägger jag ett perspektiv som kritiskt förhåller sig till uttalanden som gör gällande att vi nu funnit en lösning.

Min ambition är att i stället rikta ljuset mot, och lära mer om, de aspekter som av *nödvändighet* får stå tillbaka när kärnavfallslösningar gör framsteg. För om kärnavfallshanteringen är ett lömskt problem så har framstegen också med nödvändighet en baksida. Det innebär att jag fokuserar på det som förblir olöst, det som tonas ned, det som offras eller trycks tillbaka när slutförvarslösningarna är på väg att realiseras. En följd av detta fokus är att jag, i stället för att förstå framstegen på avfallsområdet som resultat av att kvarvarande problem nu har slutgiltigt lösts, ställer frågan om hur framstegen är möjliga *trots* de lömska problem som alltjämt karaktäriserar kärnavfallsområdet.

I min genomgång av tidigare forskning finner jag att det perspektiv som jag anlägger har varit av underordnad betydelse. Även om forskningen ibland är kritisk så har den knappast uttömt redan tillgängliga kritiska teorier i samhällsvetenskaperna. Jag menar att sådana kritiska teorier skulle kunna bidra till analysen av avfallshantering och förstå den på nya sätt.

För att finna analytiska begrepp som passar mina syften vänder jag mig till ett fält som på svenska kan kallas teknik- och vetenskapsstudier (på engelska Science and Technology Studies, STS). Detta gör jag eftersom STS erbjuder en mycket mer omfattande teoretisk apparat för det kritiska studiet av vetenskap och teknologi än vad som vanligtvis är fallet i befintliga studier av hantering av radioaktivt avfall.

Det är dock inte utan reservationer jag vänder mig till STS. Samtidigt som STS erbjuder relevanta teoretiska begrepp noterar jag också att fältet som helhet har kommit att prioritera studiet av socioteknisk förändring snarare än stabilitet. Eftersom jag är intresserad av hur avfallshantering gör framsteg trots en rad lömska problem är förklaringen till stabilitet av överordnad betydelse för mina analyser.

Med några förbehåll vänder jag mig i stället till en mindre del av STS-fältet. Jag föreslår att ”kritisk konstruktivism”, en teoribildning som bygger både på Frankfurtskolans analyser och metoder hämtade från STS, kan användas för att bättre få grepp om kärnavfallshanteringens framsteg. Genom att fokusera mer på den kritiska konstruktivismens arv från Frankfurtskolan snarare än dess STS-influenser menar jag att kärnavfallsfrågan bättre kan förstås och mina syften uppnås. Framför allt använder jag mig av begreppen ”teknisk rationalitet” och ”reifikation” (förtingligande) för att förstå hur de problem som alltjämt består på kärnavfallsområdet kan undvikas, nedtonas, eller till och med ignoreras.

Avhandlingen består i, utöver kappan, fyra delstudier. Studierna fokuserar på olika platser på kärnavfallsområdet, både i en svensk och en internationell kontext. Även om studierna har olika teoretiskt och empiriskt fokus så förenas de i sin grundläggande ambition att belysa några aspekter av avfallshantering som den dominerande tekniska rationaliteten på kärnavfallsfältet tenderar att tona ner, trivialisera, eller helt ignorera. Sammantaget bidrar studierna alltså med att kritisera och dereifiera (avförtingliga) de deltagandeprocesser som vanligtvis förstås som demokratiska. Metodologiskt sett använder jag mig av deltagande observation och dokumentanalys.

Delstudie I

I denna studie undersöker vi hur ett internationellt EU-projekt sökte integrera nya övervakningsteknologier i befintliga slutförvarsprogram. Vi noterar att många redan existerande nationella avfallshanteringsprogram hedrar så kallad passiv säkerhet, det vill säga idén att slutförvar av använt kärnbränsle och högaktivt avfall inte bör kräva några *aktiva* åtgärder för att upprätthålla säkerheten när avfallet väl har deponerats. Säkerheten ska i stället säkerställas a priori.

Under de senaste decennierna har dock krav ställts på att säkerheten behöver förbättras med mer *aktiva* åtgärder. Framstegen inom olika former av övervakningsteknologier (såsom sensorer som kan placeras djupt under jorden) har väckt intresse för om det är möjligt att förbättra säkerheten under (och även efter) stängningen av slutförvarsanläggningar. I grund och botten är passiva och aktiva åtgärder möjligtvis i konflikt med varandra på grund av deras olika förståelse om hur säkerhet kan uppnås. Kan de två på något sätt försonas eller är de ömsesidigt uteslutande?

Uppgiften att lösa denna potentiella konflikt delegerades av Europeiska kommissionen till ett projekt vid namn Modern2020. Förutom att navigera den potentiella motsättningen mellan aktiv och passiv säkerhet förväntades projektet samtidigt producera teknisk konsensus mellan dess många internationella medlemmar. Vi deltog i detta projekt och det empiriska materialet som studien bygger producerade vi genom att använda deltagande observation och dokumentanalys. I studien är vi är särskilt intresserade av att analysera hur projektet försökte navigera aktiva och passiva säkerhetsåtgärder och andra motsägelsefulla aspekter som uppstod under projektets gång.

Vi visar att aktiva och passiva säkerhetsåtgärder behandlas något olika i olika länder. Detta innebär att Modern2020 ställdes inför svårigheten att förlika nationella programskillnader. I allt väsentligt byggde de respektive nationella programmen i olika grad på passiv säkerhet. Genom att fokusera på de politiska och tekniska aspekterna som präglar två olika nationella program (det svenska och det franska) visar vi att politiska och lagstiftningsmässiga förutsättningar för övervakning skiljde sig avsevärt mellan länderna. Medan vissa former av övervakning krävdes i Frankrike var samma former av övervakning förbjudna i Sverige.

Utöver skillnader i lagstiftning noterar vi också att projekt som initieras av Europeiska kommissionen är skyldiga att upprätthålla ett antal värden. Modern2020 var därför tvunget att ta

hänsyn till EU:s kärnvärden för energipolitik, marknadsutvidgning och så vidare. Projektet förväntades hedra vissa (politiska) värden genom att producera konsensus, samtidigt som de mötte konflikter mellan olika nationella riktningar. I grund och botten skulle Modern2020 bidra till EU:s ”harmonisering” av tekniska standarder i en inte helt harmoniserad värld.

För att teoretiskt förstå denna situation vänder vi oss till Science and Technology Studies (STS). I vår teoretiska diskussion noterar vi att socio-tekniska arrangemang som försöker skapa konsensus förstås olika av teorier inom STS. Vissa forskare hävdar att konsensusambitioner är förtryckande eftersom de under täckmantel av enhetliga värden och intressen undertrycker (oundvikliga) alternativ till de dominerande värden och intressen som upprätthålls. Andra hävdar att konsensus i grunden kännetecknas av värde- och intresseheterogenitet, och betonar istället ”mångfald”. I den här artikeln kombinerar vi båda dessa tillsynes motsägelsefulla insikter för att förstå utfallet av Modern2020-projektet.

I vår analys visar vi hur den turbulens som Modern2020 mötte slutligen löstes genom att ”komma överens om att vara oense”. Genom att nå konsensus om utformningen av tekniska protokoll som tillät en viss grad av flexibilitet för de befintliga nationella programmen hedrades både de politiska värderingar som tillskrivs europeisk harmonisering och integriteten hos de olika nationella programmen. Projektet tvingade fram vad som verkade vara konsensus, men denna konsensus rymde samtidigt en viss grad av meningsskiljaktigheter. Arbetet i Modern2020 representerades slutligen ha nått teknisk konsensus, men projektet avstod från att ingripa nämnvärt i existerande nationella avfallshanteringsprogram. Detta innebär i sin tur att projektet lyckades undvika konflikt mellan aktivitet och passivitet, eftersom linjen om att ”komma överens om att vara oense” samtidigt tillät de respektive nationella programmen att följa vilka säkerhetsåtgärder de ansåg lämpliga, förutsatt att de förlitade sig på de tekniska protokoll som projektet utvecklade. Modern2020:s tekniska konsensus som den förmedlade vid projektets slut rymde alltså fortsatt spänningen mellan aktivitet och passivitet. De tekniska protokollen var dock utformade på ett sådant sätt att de både hedrade EU:s harmoniseringskrav utan att för den sakens skull ingripa i existerande program. Därför menar vi att de underliggande konflikter och motsägelser som projektet faktiskt navigerade - och som hade styrt dess uppgifter från början - i slutändan doldes av de tekniska protokollen och konsensusretoriken.

Delstudie II

I denna studie analyserar jag hur en ansökan om att bygga en slutförvarsanläggning för använt kärnbränsle granskades i en svensk domstol. I domstolen blev frågan om de kopparkapslar som ska innesluta avfallet i berggrunden central och en kontrovers om kopparkorrosion blossade upp. Genom att hänvisa till *fakta* övertygade till slut motexperter och miljöorganisationer domstolen om att korrosionsrisken utgjorde en verklig fara, ett hot mot säkerheten. Parterna som deltog i kontroversen var alltså inte explicit engagerade i ”bredare” frågor om rättvisa, energipolitik och så vidare. Snarare var det de strikt vetenskapliga aspekterna av ansökan som skapade uppmärksamhet och oenighet.

I denna studie föreslår jag att kontroversen aktualiserar en teoretisk spänning inom teknik- och vetenskapsstudier (Science and Technology Studies, STS). Denna spänning består i att forskning inom STS är ambivalent om huruvida det är fruktbart att studera kontroverser som förblir strikt tekniska och vetenskapliga trots allmänhetens deltagande. STS tenderar att prioritera kontroverser där allmänhet och lekmän *utmanar* experters tekniska ramverk genom att belysa de bredare frågorna som experter ofta förbiser. Ibland talar man om att de tekniska ramverken börjar ”läcka” när lekmän engagerar sig i tekniska frågor. Detta fokus menar jag missar betydelsen av kontroverser där bredare frågor envist förblir osynliga och där de tekniska ramverken inte ”läcker”. I allt väsentligt förblev kopparkontroversen vetenskaplig och teknisk. Samtidigt presenterar kontroversen möjligheten att teoretiskt utveckla vad jag kallar ”tröga” kontroverser, det vill säga kontroverser som inte ”läcker”.

Med några förbehåll föreslår jag att Andrew Feenbergs kritiska konstruktivism - en blandning av STS och Frankfurt-skolan - kan bidra. Ett första bidrag är dess möjlighet att förklara varför kontroverser förblir tröga och inte läcker. Ett ytterligare bidrag är kritisk konstruktivism kan göra explicita de implicita bredare frågorna, och därmed oberoende av läckage identifiera vad som står på spel. För att kunna göra dessa bidrag menar jag emellertid att den kritiska konstruktivismen behöver betona mer sitt kritiska arv. Precis som många samtida studier inom STS har den kritiska konstruktivismen alltmer kommit att utveckla förståelsen av förändring. Dock har den gjort så på bekostnad av Frankfurt-skolans kritik av status quo.

Genom att åberopa historiska idéer i STS som gör gällande att kontroversers avslut kan åstadkommas av hegemoniska strukturer kan det jag kallar tröga kontroverser förstås med hjälp av kritisk konstruktivism. Detta menar jag bidrar till förståelsen av en bredare uppsättning kontroverser inom STS. Framför allt utvecklar jag hur ”teknisk rationalitet” - en dominerande

form av rationalitet och struktur i moderna samhällen - kan användas som ett teoretiskt redskap för att förstå varför kontroverser som inte läcker.

Metodologiskt förlitar jag mig på deltagande observation i domstolen men jag ger också en kort historik över svensk avfallshantering för att kontextualisera kontroversen. Min huvudsakliga slutsats från detta avsnitt är att viktiga aktörer inom fältet framgångsrikt har lyckats rama in frågor om kärnavfall som radikalt skilda från exempelvis energipolitik och andra kontroversiella frågor. Avfallshantering har i allt väsentligt förståtts som en strikt teknisk fråga som kräver tekniskt kunnande. Som en följd av denna föreställning har möjligheten att yttra kritik begränsats. För att verka ”rationell” i detta sammanhang måste även lekmän engagera sig i tekniska frågor. Kort sagt framstår icke-tekniska resonemang som irrationella, eller som subjektivt politiska.

Från denna bakgrund framstår de efterföljande händelserna i domstolen som mindre överraskande. Genom att förlita mig på mina observationer visar jag en process som var upptagen med de vetenskapliga aspekterna av korrosion. Medan hantering av kärnavfall berör en rad aspekter som man skulle kunna förvänta sig att lekmän skulle beröra förblev läckorna få. I stället underblåste domstolen den tekniska inramningen genom att kräva ”objektivitet” och hänvisning till fakta. Till slut drog domstolen slutsatsen att osäkerheten i kunskapen om korrosion motiverade ett stopp i ansökningsprocessen.

Medan detta uppfattades som en seger inom miljörörelsen föreslår jag att utfallet representerar en seger för dem som har ett intresse av att hävda att avfallshantering är en strikt teknisk fråga. Jag menar vidare att händelserna i domstolen var resultatet av en (tekniskt rationell) kultur som har utvecklats över tid. Förståelse av kontroversens villkor kräver att man överväger det som inte var omedelbart närvarande under förfarandena, det vill säga strukturerna som villkorade kontroversen. Avslutningsvis kan kritisk konstruktivism, med vissa förbehåll, framgångsrikt användas i kontroverser där det finns få eller inga läckor. Detta menar jag bidrar till STS möjlighet att analysera ett bredare spektrum av kontroverser.

Delstudie III

Tekniska experter på kärnavfallshanteringsområdet hävdar ofta att de har en säker teknologi för att hantera använt kärnbränsle. Geologisk slutförvaring (att placera använt kärnbränsle och högaktivt kärnavfall djupt under marken i kapslar) föreslås vara lösningen på avfallsproblemet. Trots teknisk konsensus har det ändå visat sig vara svårt att hitta platser där geologisk slutförvaring kan realiseras. Detta beror på att det oftast finns lokalt motstånd på platser som föreslagits vara lämpliga för geologisk slutförvaring.

Motståndet har visat att lokalsamhället inte kan förbises i platsundersökningar och placering av slutförvarsanläggningar. Aktörer som söker implementera slutförvarsanläggningar försöker därför nu att interagera med allmänheten för att få deras ”acceptans”. Denna nya typ av interaktion har dock visat sig vara belastad av asymmetriska maktförhållanden mellan lokalbefolkning och dem som söker implementera. Ofta kontrollerar och dominerar de senare de processer som ska skapa acceptans. Mot bakgrund av denna erfarenhet har tidigare forskning föreslagit att maktasymmetrin ska brytas medelst större inkludering av allmänhet och lekmän. Ofta säger forskningen att den som söker implementera måste lära sig att ta större hänsyn till allmänna intressen. Ofta representeras allmänhetens *samtycke* i detta sammanhang som en garant för att ”rättvis” förläggning av slutförvar har ägt rum.

I denna studie problematiserar jag denna idé genom att ge exempel på hur mäktiga aktörer i Sverige försöker skapa samtycke. Jag menar att Sverige är ett viktigt fall att studera eftersom det svenska kärnavfallsprogrammet internationellt anses vara en förebild. Andra länder som kämpar med att lokalisera en plats där avfallet kan deponeras vänder sig ofta mot Sverige för att lära sig mer om hur demokratiska processer kan leda till acceptans.

I kommunen Östhammar, den föreslagna platsen för ett svenskt slutförvar, sägs det finnas brett stöd för industrins platsundersökningar. Vidare sägs allmänheten samtycka till framtida konstruktion av en anläggning för använt kärnbränsle. Tidigare forskning har dock ännu inte visat eller förstått mer detaljerat hur samtycket uppstått, eller producerats. För att bättre förstå den svenska förebilden och den typ av samtycke som skapats analyserar jag kärnkraftsindustrins skriftliga material som distribueras till medborgarna i Östhammar. Detta material utgörs av Lagerbladet, en tidskrift producerad av industrin med lokala medborgare som avsedd målgrupp.

Jag inleder med att kontextualisera hur strävan efter att nå samtycke har uppstått. Jag visar att svenska kommuners vetorätt när det kommer till slutförvarsanläggningars placering, samt hur allmänhetens motstånd har sett ut historiskt, har resulterat i en kreativ förläggningsstrategi som

har övergivit mer tvingande försök att finna en plats. I stället siktar nu aktörer som söker en plats att bygga slutförvar på att skapa samtycke genom att ta hänsyn till lokala intressen och kultur. Denna utvecklade strategi menar jag i mångt och mycket motsvarar tidigare forsknings uppmaning till aktörer som söker en plats att bygga slutförvar att ta hänsyn till allmänhetens intressen och viljor. Jag föreslår dock att strategin alltjämt aktualiserar en rad problem.

Jag bygger denna förståelse på teoretiska begrepp som förstår produktionen av samtycke som en specifik form av maktutövning. I stället för att ses som ett slutmål ses samtyckesproduktionen ur detta perspektiv som en taktik som mäktiga aktörer använder för att förhindra motstånd och undvika konflikt. Med detta i åtanke framstår samtyckesstrategin som mindre idealisk. I stället för att dra slutsatsen att Sverige har utvecklats på ett särskilt demokratiskt sätt föreslår jag att den svenska industrin utövar ”tredje dimensionens makt” för att uppnå sina mål. Med det menar jag att kärnkraftsindustrin har naturaliserat särskilda (partiska) problemrepresentationer och reduktionistiska idéer. Exempelvis visar jag i min analys av det empiriska materialet att man försöker sudda ut distinktioner mellan industrin och den lokala allmänheten, att man presenterar industrins och den lokala allmänhetens intressen som i grunden de samma, att man konstruerar vad som är en ”god” och ”dålig” medborgare, och så vidare. Industrins strategi för att nå samtycke är därför partisk och målar upp en begränsad bild av de problem som förläggningsprocessen kan sägas innebära.

Med hänsyn till dessa resultat drar jag slutsatsen att inkluderingen av lokala intressen inte är någon universalmedicin för rättvisa och att lokaliseringsprocesser för slutförvarsanläggningar i realiteten är oundvikligt orättvisa. I stället för att försöka skapa bättre deltagande, vilket mycket forskning redan har gjort, föreslår jag nya sätt att studera lokaliseringskontroverser. Ett sådant projekt föreslår jag kan inspireras av studiet av sociala rörelser och miljöaktivism där kritiska maktteorier redan är vanliga. Dock har sådana maktteorier används sparsamt i studier på kärnavfallsområdet.

Delstudie IV

Det som återstår efter reaktordrift, det vill säga använt kärnbränsle och högaktivt avfall, anses av de flesta tekniska experter bäst hanterat medelst ”geologisk slutförvaring”. Djupt i berggrunden på ett säkert avstånd från biosfären ska avfallet sedan ligga för evigt. Även om säkra koncept för geologisk slutförvaring presenterades som inom räckhåll för modern vetenskap och teknik redan för nästan ett halvt sekel sedan har dock själva förläggningen av slutförvarsanläggningar visat sig vara svår att slutföra. Med några få undantag i norra Europa emotsätter sig vanligtvis allmänheten lokaliseringsförsök.

Tidigare forskning har visat att lokaliseringsförsök har präglats av teknokratiska förfaranden. Ofta har ansvariga aktörer argumenterat för att lokalisering ska styras av tekniska kriterier såsom exempelvis berggrundens sammansättning. Lokaliseringsprocesser har därför historiskt sett inte tagit hänsyn till allmänhetens önskningar eller känslor i frågan. I stället var det den vetenskapliga ”sanningen” som skulle avgöra platsen. Känslor, som ofta förstås som motsatsen till sanning, har därför historiskt sett avvisats som irrelevanta, eller till och med som ”irrationella distraktioner” som står i vägen för lyckad förläggning av slutförvarsanläggningar.

Denna syn som ibland har haft inslag av tvång har emellertid utvecklats under de senaste decennierna. Det vanliga förfarandet är nu att allmänheten bjuds in till diskussioner vid platsundersökningar, inte minst för att begränsa motstånd. Följaktligen har tidigare forskning fokuserat på de nya former av engagemang i lokalsamhällen som uppkommit efter de mer tvingande förläggningsförsöken. Även om diskussionerna är alltjämt teknokratiskt präglade så förstås nu förläggningsprocesser av både genomförare och forskare som beroende av känslor, såsom exempelvis (ömsesidigt) förtroende och tillit.

I den här artikeln föreslår vi att övergången från förfaranden som hänvisade till vetenskaplig ”sanning” fri från emotioner, till mer interaktiva former av deltagande som tar hänsyn till också ”mjukare” aspekter av förläggning av slutförvarsanläggningar kan förstås som en process genom vilken relationen mellan rationalitet och känslor har förändrats. Känslor är nu viktiga i kärnavfallshantering på ett sätt som är märkbart kontrasterar historiska tillvägagångssätt. Dock är det fortfarande oklart hur, mer precist, känslor hanteras och införlivas i förläggningsprocesser.

Relationen mellan rationalitet och känslor är i sin tur är en av de teoretiska specialiteterna i en typ av sociologi som specialiserat sig på studiet av emotioner. För att lära oss mer analyserar vi samtida policy som i detalj redogör för hur känslorna nu ska få ta plats. Teoretiskt sett,

eftersom rationalitet och känslor är oupplösligt sammanflätade, förstår vi det som vårt centrala uppdrag att förstå de specifika sätt genom vilka känslor och rationalitet är sammanvävda, enligt policy. Genom att utforska vilka känslor som tillskrivs allmänheten i policy analyserar vi vilken form av rationalitet och känslor som hålls som ideala. Vilka känslor är viktiga i policyns ”sanningsregim”? Vilka känslor representeras som rationella och irrationella?

I vår analys utforskar vi och förstår samtida policy som ett exempel på ”diskursiv projicering”. Med detta menar vi att det som framkommer i materialet inte utgör en ”sann” redogörelse för vad som karaktäriserar allmänhetens känslor utan snarare en indikation på policyns förståelse av allmänhetens känslor, av det som är rationellt och det som inte är det. I analysen menar vi att policyn preciserar ett slags ”känsloregim”, det vill säga en serie regler som etablerar vilka känslor som är kompatibla (och vilka som inte är det) med ”sanningen” att slutförvaring av uttjänt kärnbränsle utgör den bästa lösningen på avfallsproblemet.

Genom att förstå relationen mellan känslor och förnuft utifrån ett emotionsociologiskt perspektiv visar vi hur känsloregimen i policy har förvandlats från att representera en tydligt konventionell uppfattning som förstår rationalitet och känslor som oförenliga, till en vid första anblick mer radikal förståelse av relationen mellan rationalitet och känslor. Analysen visar vilka känslor som beskrivs som hot mot förnuftet och vilka som beskrivs som hjälpmedel för implementerarnas förnuft och rationalitet, vilka känslor som idealiseras - och vilka som avvisas. Vi drar slutsatsen att vi inte kan förstå det nya fokuset på känslor i NWM som ovillkorligt. Medan det nya fokuset vid första anblicken kan verka radikalt, visar det sig att när det studeras närmare upprätthåller det många av de befintliga teknokratiska idéerna i NWM som kritiserats av tidigare forskning. Förändringen från en konventionell syn på relationen mellan rationalitet och känslor till det vi har kallat en mer 'kritisk' syn bör därför inte överdrivas. I verkligheten står den konventionella synen fortfarande stark på många sätt.

Slutsatser

Enligt de tolkningar jag gör i avhandlingen så kan inte framstegen på kärnavfallsområdet förstås som ett resultat av en öppen, transparent och demokratisk process, vilket annars är en vanlig uppfattning. I stället visar jag att centrala aktörer på fältet har förmågan att utesluta och/eller tona ned viss kritik, missnöje och opposition som annars skulle kunna belysa de ”lömska problem” som jag menar präglar fältet.

I allt väsentligt möjliggör den rationalitet som jag kallar teknisk att man kan bortse från kärnavfallshanteringens problem, dess relation till kärnkraft, och hur den är historiskt och strukturellt villkorad. I avhandlingen kallar jag det för att kärnavfallsfältet har reifierats (förtingligats) i enlighet med den tekniska rationalitetens reduktionism. Med det menar jag att sociala relationer, motsägelsefulla intressen och alla de problem som avfallshantering aktualiserar har reducerats till frågor om teknisk görbarhet. Reifikationen är alltså det som möjliggör de diskurser och praktiker som omgärdar avfallsfrågan och som hanterar avfallet som skiljt från den kontext i vilken den är inbäddad.

En viktig poäng är alltså att problemen inte försvinner utan snarare döljs. Genom fyra delstudier har jag sökt att dereifiera åtminstone några aspekter av avfallshanteringen som jag menar döljs bakom de tekniska frågorna. Denna dereifikation kan sägas bestå i att jag genom de fyra delstudierna undersöker både hur motsägelsefulla sociala intressen navigeras, hur de görs till tekniska frågor och hur konflikt undviks. Genom att studera avfallsfrågan på detta sätt blir det möjligt att fokusera på vad som händer med de lömska problem som präglar fältet.

Jag finner att styrningen av avfallshanteringen har flera konsekvenser som den själv inte vidkänner. I den kultur som råder på kärnavfallshanteringsfältet, som präglas av en dominerande teknisk rationalitet, visar jag hur teknisk och vetenskaplig kritik får företräde framför annan typ av kritik. Vetenskaplig och teknisk detaljgranskning överordnas annan typ av reflektion. Detta innebär att exempelvis levd erfarenhet, kritiskt tänkande och etisk och politisk reflektion underordnas teknisk kunskap och tekniskt nagelfarande. Samtidigt visar jag att den tekniska kunskapen inte är neutral. Tvärtom understödjer den, om än inte explicit, en rad etiska principer och politiska värden. Att demonstrera en tekniskt rationell och ”säker” slutförvarslösning är till exempel avgörande för att kunna legitimera nuvarande och framtida kärnkraft.

Att aktörer inom kärnavfallshantering nu har tagit steg mot att implementera geologisk slutförvaring, trots de baksidor och problem som jag belyser i avhandlingen, benämner jag ”villkorade framsteg”. Med det menar jag att implementering ofrånkomligen kommer att vara

partisk i den bemärkelsen att vissa sociala intressen kommer att gynnas över andra sociala intressen. Framstegen har alltså konsekvenser och dessa konsekvenser illustreras i de enskilda studierna. Mina slutsatser om framstegen som villkorade skiljer sig från en stor del av den tidigare forskning som ofta antyder att framsteg åtminstone i princip kan göras på ett demokratiskt och legitimt sätt. Till tidigare forskning bidrar avhandlingen med perspektiv som tidigare inte anlagts.

Dessa slutsatser kan verka dystopiska, men jag menar att det finns saker att lära från kärnavfallsfältet för andra fält. Även om den demokratiska potentialen på kärnavfallsområdet är begränsad och dess framsteg villkorade så betyder inte det att det nödvändigtvis förhåller sig på detta vis på andra områden. Snarare utgör kärnavfallsområdet ett slags varnade exempel för hur den tekniska rationalitetens framfart kan skapa olösliga problem som kringskär möjligheterna att demokratiskt styra teknologiutveckling. Enligt mina slutsatser finns det allså anledning att identifiera den teknologiska hybris som finns på kärnavfallsfältet även på andra fält. De begrepp och teorier jag har använt underlättar ett sådant projekt.

9 References

Alvesson, M. & Sköldberg, K. (2009) *Reflexive methodology: new vistas for qualitative research*. 2. ed. Los Angeles: SAGE

Andrén, M. (2012a) *Nuclear waste management and legitimacy: nihilism and responsibility*. Abingdon, Oxon: Earthscan.

Andrén, M. (2012b) An Uncomfortable Responsibility: Ethics and Nuclear Waste. *The European Legacy*, 17(1), 71-82.

Anshelm, J. (2000) *Mellan frälsning och domedag: om kärnkraftens politiska idéhistoria i Sverige 1945-1999*. Eslöv: B. Östlings bokförl. Symposion.

Anshelm, J. (2006a) *Bergsäkert eller våghalsigt?: frågan om kärnavfallets hantering i det offentliga samtalet i Sverige 1950-2002*. Lund: Arkiv.

Anshelm, J. (2006b) *Från energiresurs till kvittblivningsproblem: frågan om kärnavfallets hantering i det offentliga samtalet i Sverige, 1950-2002*. Stockholm: SKB.

Anshelm, J. & Galis, V. (2011) (Re-)constructing Nuclear Waste Management in Sweden : The Involvement of ConcernedGroups, 1970–2010. In: *Integrated Waste Management - Volume II* (Ed.) Kumar, S., 401–430.

Asdal, K. & Reinertsen, H. (2020) *Hvordan gjøre dokumentanalyse: en praksisorientert metode*. 1. utgave Oslo: Cappelen Damm akademisk.

Auffermann, B., Suomela, P., Kaivo-oja, J., Vehmas, J. & Luukkanen, J. (2015) A final solution for a big challenge? The governance of nuclear waste disposal in Finland. In: *Nuclear Waste Governance: An International Comparison.* (Eds.) A. Brunnengräber, M. R., Di Nucci, A. M. I., Losada, L., Mez & Schreurs, M. A. Springer. Wiesbaden: Springer Fachmedien Wiesbaden.

Bacchi, C. (2009) *Analysing policy: what's the problem represented to be?* Frenchs Forest: Pearson.

Bacchi, C. (2012) Introducing the 'What's the Problem Represented to be?' approach. In *Engaging with Carol Bacchi: Strategic Interventions and Exchanges.* (Eds.) A. Bletsas & C. Beasley, 21-24. The University of Adelaide Press.

Barbalet, J. (2011) Emotions Beyond Regulation: Backgrounded Emotions in Science and Trust. *Emotion Review,* 3(1), 36-43.

Barbalet, J. (2001) *Emotion, social theory, and social structure: A macrosociological approach*. Cambridge: Cambridge University Press.

Barbalet, J. (2002) Science and Emotions. *The Sociological Review,* 50(2), 132-150.

Barthe, Y. (2009) Framing nuclear waste as a political issue in France. *Journal of Risk Research,* 12(7-8), 941-954.

Barthe, Y., Elam, M. & Sundqvist, G. (2020) Technological Fix or Divisible Object of Collective Concern? Histories of Conflict over the Geological Disposal of Nuclear Waste in Sweden and France. *Science As Culture,* 29(2), 196-218.

Barthe, Y. & Mays, C. (2001) Communication and information in France's underground laboratory siting process: Clarity of procedure, ambivalence of effects. *Journal of Risk Research, 4*(4), 411-430.

BBC (2022) *Climate change: EU moves to label nuclear and gas as sustainable despite internal row.* Retrieved 0506, 2022, from https://www.bbc.com/news/world-europe-60229199

Beaulieu, A. (2010) From co-location to co-presence: Shifts in the use of ethnography for the study of knowledge. *Social Studies of Science,* 40(3), 453-470.

Bell, M. (2021) Spatialising procedural justice: Fairness and local knowledge mobilisation in nuclear waste siting. *Local Environment,* 26(1), 165-180.

Bergmans, A., Elam, M., Kos, D., Polic, M., Simmons, P., Sundqvist, G. & Walls, J. (2008) *Wanting the Unwanted: Effects of Public and Stakeholder Involvement in the Long-Term Management of Radioactive Waste and the Siting of Repository Facilities*. CARL Report.

Bergmans, A., Sundqvist, G., Kos, D. & Simmons, P. (2015) The participatory turn in radioactive waste management: Deliberation and the social-technical divide. *Journal of Risk Research,* 18(3), 347-363.

Birch, K. (2017) Techno-economic Assumptions. *Science as Culture,* 26(4), 433-444.

Blowers, A. (2010) Why dump on us? Power, pragmatism and the periphery in the siting of new nuclear reactors in the UK. *Journal of Integrative Environmental Sciences*, 7(3), 157-173.

Blowers, A. (2016) *The legacy of nuclear power.* Abingdon, UK: Routledge.

Blowers, A. & Sundqvist, G. (2010) Radioactive waste management – technocratic dominance in an age of participation. *Journal Of Integrative Environmental Sciences, 2010,* s, 149-.155.

Brunnengräber, A. (**2015**) *Nuclear Waste Governance: An International Comparison*. Wiesbaden: Springer Fachmedien Wiesbaden.

Bråkenhielm, C. (2015) Ethics and the management of spent nuclear fuel. *Journal of Risk Research,* 18(3), 392-405.

Burawoy, M. (2005) For Public Sociology. *American Sociological Review,* 70(1), 4-28

Bösch, F. (2017) Taming nuclear power: The accident near Harrisburg and the change in West German and international nuclear policy in the 1970s and early 1980s. *German History,* 35(1), 71-95.

Callon, M., Lascoumes, P. & Barthe, Y. (2009) *Acting in an uncertain world: An essay on technical democracy*. Cambridge: MIT Press.

Cassegård, C. (2021) *Toward a critical theory of nature : Capital, ecology, and dialectics*. Bloomsbury Publishing.

Collins, H.M. (1984) Researching Spoonbending: Concepts and Practice of Participatory Fieldwork. In: *Social Researching: Politics, Problems, Practice.* (Eds.) C. Bell and H. Roberts, 54-69. London: Routledge and Kegan Paul.

Dawson, J. & Darst, R. (2006) Meeting the challenge of permanent nuclear waste disposal in an expanding Europe: Transparency, trust and democracy. *Environmental Politics,* 15(4), 610-627.

Di Nucci, M., Isidoro Losada, A. & Themann, D. (2022) Confidence gap or timid trust building? The role of trust in the evolution of the nuclear waste governance in Germany. *Journal of Risk Research,* 25(5), 594-612.

Dilot, T. (2015) *Kärnkraften hållbar och klimatsmart*. Svenska Dagbladet 20150515. Retreived 0418, 2023, from https://www.svd.se/a/30dcdbdb-e2fc-3e7e-aead-419cbbed9715/karnkraften-hallbar-och-klimatsmart

Dilot, T. (2016) *Svensk teknik ger ny kärnkraft med miljövinster*. Svenska Dagbladet 20161192. Retreived 0511, 2022, from https://www.svd.se/svensk-teknik-kan-ge-klimatsmart-ny-karnkraft

Ekomodernisterna (2022) *Ekomodernisterna*. Retrieved 0510, 2022, from https://ekomodernisterna.se/

Elam, M. & Sundqvist, G. (2009) The Swedish KBS project: A last word in nuclear fuel safety prepares to conquer the world? *Journal of Risk Research,* 12(7-8), 969-988.

Elam, M. & Sundqvist, G. (2010) Demonstrating Safety - Validating New Build: The Enduring Template of Swedish Nuclear Waste Management. *Journal Of Integrative Environmental Sciences,* 7(3), 197-210.

Elam, M. & Sundqvist, G. (2011) Meddling in Swedish success in nuclear waste management. *Environmental Politics,* 20(2), 246-263.

European Commission (2020) *Harmonised Standards*. Retrieved 0212, 2020, from https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards_en

Feenberg, A. (1999) *Questioning technology*. London: Routledge.

Feenberg, A. (2017a) Critical theory of technology and STS. *Thesis Eleven,* 138(1), 3-1.

Feenberg, A. (2017b) *Technosystem*. Cambridge: Harvard University Press.

Feenberg, A. (2020) Critical Constructivism: An Exposition and Defense *Logos: A journal of modern society and culture*. Retrieved 0418, 2023, from: https://logosjournal.com/2020/critical-constructivism-an-exposition-and-defense/

Heimersson, A. (2020) *Vänsterns kärnkraftsmotstånd vacklar*. Dagens arena 20200309. Retrieved 0511, 2022, from https://www.dagensarena.se/innehall/vansterns-karnkraftsmotstand-vacklar/

Hess, D. J. (2001) Ethnography and the development of science and technology studies, in *Sage Handbook of Ethnography* (Eds.) Atkinson, P., Coffey, A., Delamont, S., Lofland, J. & Lofland, L. Thousand Oaks: Sage Publications.

Hietala, M. & Geysmans, R. (2022) Social sciences and radioactive waste management: Acceptance, acceptability, and a persisting socio-technical divide. *Journal of Risk Research,* 25(4), 423-438.

Hocke, P. & Renn, O. (2009) Concerned public and the paralysis of decision-making: Nuclear waste management policy in Germany. *Journal of Risk Research,* 12(7-8), 921-940.

Hornborg, A. (2019) *Nature, society, and justice in the anthropocene: unraveling the money-energy-technology complex*. Cambridge: Cambridge University Press.

Hultquist, G. (1986) Hydrogen evolution in corrosion of copper in pure water. *Corrosion Science* 26(2), 173-177.

IAEA (2017) *IAEA Meeting Highlights Public Trust Crucial in Nuclear Power*. Retrieved 0331, 2020, from https://www.iaea.org/newscenter/news/iaea-meeting-highlights-public-trust-crucial-in-nuclear-power

IAEA (2020) *Developing Trust as a Communication Principle*. Retrieved 0331, 2020, from https://www.iaea.org/resources/nuclear-communicators-toolbox/basics/trust

IAEA (2021) *Engaging Opposing Views*. Retrieved 1110, 2021, from https://www.iaea.org/resources/nuclear-communicators-toolbox/basics/trust/opposing-views

IGD-TP (2016) *Implementing Geological Disposal of Radioactive Waste Technology Platform*. Retrieved 0823, 2016, from http://www.igdtp.eu/index.php/presentation

IPCC (2018) *Climate Change 2007: Working Group III: Mitigation of Climate Change*. Retrieved 0207, 2018, from https://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch2s2-7-1.html

Johansson, E. (2021) *SKB väljer Östhammar*. Västervikstidningen. Retrieved 1201, 2021, from https://vt.se/nyheter/skb-valjer-osthammar-4938908.aspx

Kaiserfeld, T. & Kaijser, A. (2021). Changing the System Culture: Mobilizing the Social Sciences in the Swedish Nuclear Waste System. *Nuclear Technology,* 207(9), 1456-1468.

Kaltenbrunner, W., Birch, K., Van Leeuwen, T. & Amuchastegui, M. (2022) Changing publication practices and the typification of the journal article in science and technology studies. *Social Studies of Science,* 52(5), 758-782.

Katz-Rosene, R. (2021) 'Don't Think of Fukushima!': The Ethics of Risk Reframing in 'Nuclear for Climate' Communications. *Ethics, Policy & Environment,* 24(2), 164-186.

KBS (1978a) *Handling and Final Storage of Unreprocessed Spent Nuclear Fuel. I General.* Stockholm: KBS.

KBS (1978b) *Handling and Final Storage of Unreprocessed Spent Nuclear Fuel. I Technical.* Stockholm: KBS.

Kitschelt, H. (1986) Political Opportunity Structures and Political Protest: Anti-Nuclear Movements in Four Democracies. *British Journal of Political Science,* 16(1), 57-85.

Knutson, M. (2021) *Analys: Kärnkraften kan bli het valfråga.* Retrieved 1215, 2021, from https://www.svt.se/nyheter/inrikes/analys-karnkraften-kan-bli-het-valfraga

Kojo, M. & A. Oksa (2014) *Adaption of the Swedish KBS disposal concept to Finland: A technology transfer case study.* INSOTECH Report. Retreived 0418, 2023, from: https://trepo.tuni.fi/handle/10024/95667

Konopásek, Z., Soneryd, L. & Svačina, K. (2018) Lost in translation: Czech dialogues by swedish design. *Science & Technology Studies,* 31(3), 5-23.

Krütli, P., Stauffacher, M., Pedolin, D., Moser, C. & Scholz, R. (2012) The Process Matters: Fairness in Repository Siting For Nuclear Waste. *Social Justice Research,* 25(1), 79-101.

Lagerbladet Oskarshamn (2016) Lagerbladet Oskarshamn. Oskarshamn: SKB.

Lagerlöf, H., Sundqvist, G. & Bergmans, A. (**2022**) Striving for technical consensus by agreeing to disagree: The case of monitoring underground nuclear waste disposal facilities. *Journal Of Risk Research,* 25(5), 666-679.

Land and Environmental Court (2017) *Ansökan om slutförvar av använt kärnbränsle m.m.* Retrieved 0108, 2018, from http://www.nackatingsratt.domstol.se/Om-tingsratten/Uppmarksammade-mal/Ansokan-om-slutforvar-for-anvant-karnbransle-mm/

Latour, B. (1987) *Science in action: How to follow scientists and engineers through society*. Cambridge: Harvard University Press.

Latour, B. & Woolgar, S. (1986) *Laboratory life: The construction of scientific facts*. Princeton: Princeton University Press.

Lave, R., Mirowski, P. & Randalls, S. (2010) Introduction: STS and Neoliberal Science. *Social Studies of Science,* 40(5), 659-675.

Levin, D. (2021) *Kärnkraftsmotståndet i Sverige ökar: "En tydlig övervikt".* Dagens industri 20210320. Retrieved 0302, 2022, from https://www.di.se/nyheter/karnkraftsmotstandet-i-sverige-okar-en-tydlig-overvikt/

Lidskog, R. & Andersson, A. (2002) *The management of radioactive waste: A description of ten countries.* Stockholm: Svensk kärnbränslehantering AB.

Lindström, O. (2021) *Rekordstort stöd för ny kärnkraft.* Svenska dagbladet 20210627. Retrieved 1208, 2021, from https://www.svd.se/rekordstort-stod-for-ny-karnkraft

Litmanen, T., Kari, M., Kojo, M. & Solomon, B. (2017) Is there a Nordic model of final disposal of spent nuclear fuel? Governance insights from Finland and Sweden. *Energy Research & Social Science,* 25, 19-30.

Lukes, S. (2021) *Power: a radical view*. London, Macmillian Education.

Marcuse, H. (2002) *One-dimensional man: studies in the ideology of advanced industrial society.* London: Routledge.

Moderaterna (2022) *Kärnkraft är klimatsmart.* Retrieved 0506, 2022, from https://moderaterna.se/var-politik/karnkraft/

Modern2020 (2015a) *Development and Demonstration of monitoring strategies and technologies for geological disposal.* Retrieved 0119, 2016, from http://cordis.europa.eu/project/rcn/196921_en.html

Modern2020 (2015b) *Modern2020.* Retrieved 0212, 2016, from http://www.modern2020.eu/

Modern2020 (2016) *About Modern2020*. Retrieved 0830, 2016, from http://www.modern2020.eu/about-us/about-modern2020.html

Moore, K. (2021) Capitalisms, Generative Projects and the New STS. *Science as Culture,* 30(1), 58-73.

Mussell, S. (2017) *Critical theory and feeling.* Manchester: Manchester University Press.

Naturskyddsföreningen (2021) *Vanliga frågor om kärnkraft.* Retrieved 0511, 2022, from https://www.naturskyddsforeningen.se/artiklar/vanliga-fragor-om-karnkraft/

NEA (2007) *Fostering a Durable Relationship Between a Waste Management Facility and its Host Community: Adding Value through Design and Process.* Retrieved 0618, 2021, from https://oecd-nea.org/jcms/pl_18420/fostering-a-durable-relationship-between-a-waste-management-facility-and-its-host-community-adding-value-through-design-and-process

NEA (2012) *Geological Disposal of Radioactive Waste: National Commitment, Local and Regional Involvement*. Retrieved 0824, 2022, from https://www.oecd-nea.org/jcms/pl_14794/geological-disposal-of-radioactive-waste-national-commitment-local-and-regional-involvement?details=true

NEA (2015) *Fostering a durable relationship between a waste management facility and its host community*. Retrieved 1123, 2020, from https://www.oecd-nea.org/jcms/pl_14966/fostering-a-durable-relationship-between-a-waste-management-facility-and-its-host-community

NEA (2019) *The Nuclear Energy Agency*. Retrieved 1113, 2019, from https://www.oecd-nea.org/

NEA (2022) *Meeting Climate Change Targets: The Role of Nuclear Energy*. Retrieved 0418, 2023, from https://www.oecd-nea.org/jcms/pl_69396/meeting-climate-change-targets-the-role-of-nuclear-energy

Näringsutskottet (1976) NU 1976/77:23.

OECD-NEA (2010) *Public Attitudes to Nuclear Power*. Retrieved 0403, 2020, from https://www.oecd-nea.org/ndd/pubs/2010/6859-public-attitudes.pdf

OECD-NEA (2019) *The Environmental and Ethical Basis of Geological Disposal of Long-Lived Radioactive Wastes*. Retrieved 0418, 2023, from http://www.tdb.oecd-nea.org/rwm/reports/1995/geodisp-entire-report.html

Okrent, D. & Pidgeon, N. (2000). Introduction: Dilemmas in Intergenerational versus Intragenerational Equity and Risk Policy. *Risk Analysis,* 20(6), 759-76

Orring, A. (2017) *Striden om slutförvaret: "Kapslar börjar kollapsa efter 100 år"*. Ny teknik 20170908. Retrieved 0328, 2022, from https://www.nyteknik.se/energi/striden-om-slutforvaret-kapslar-borjar-kollapsa-efter-100-ar-6869595

Oughton, D. & Howard, B. (2012). The Social and Ethical Challenges of Radiation Risk Management. *Ethics, Policy & Environment,* 15(1), 71-76.

Parotte, C. & Delvenne, P. (2015). Taming uncertainty: Towards a new governance approach for nuclear waste management in Belgium. *Technology Analysis & Strategic Management,* 27(8), 986-998.

Pfister, E. (2015). Nuclear optimism in European newsreels in the 1950s. *Zeitgeschichte,* 42(5), 285-298.

Philipsson, T. (2021) *Kärnkraften som en tredje väg*. Retrieved 1207, 2021, from https://www.vansterpartiet.se/debatt/karnkraften-som-en-tredje-vag/

Regeringen (2022) *Regeringen tillåter slutförvar av använt kärnbränsle i Forsmark*. Retrieved 0503, 2022, from https://regeringen.se/pressmeddelanden/2022/01/regeringen-tillater-slutforvar-av-anvant-karnbransle-i-forsmark/

Rittel, W.J. & Webber, M. (1973) Dilemmas in a General Theory of Planning. *Policy Sciences,* 4(2), 155-169.

Rossignol, N., Parotte, C., Joris, G. & Fallon, C. (2017) Siting controversies analysis: Framework and method for questioning the procedure. *Journal of Risk Research,* 20(10), 1253-1274.

Saito, H. & Pahk, S. (**2016**) The Realpolitik of Nuclear Risk: When Political Expediency Trumps Technical Democracy. *Science, Technology & Society,* 21(1), 5-23.

Seidl, R., Drögemüller, C., Krütli, P. & Walther, C. (2022) The role of trust and risk perception in current German nuclear waste management. *Risk Analysis,* 42(12), 2704-2719.

SFS (1977:140) *Lag om särskilt tillstånd att tillföra kärnreaktor kärnbränsle, m.m.* (Villkorslagen, 1977).

SFS (1984:3) *Lag om kärnteknisk verksamhet.*

SFS (2003:460) *Lag (2003:460) om etikprövning av forskning som avser människor.*

Shelley, F., Solomon, B., Pasqualetti, M. & Murauskas, G. (1988). Locational Conflict and the Siting of Nuclear Waste Disposal Repositories: An International Appraisal. *Environment and Planning. C,* 6(3), 323-333.

Sismondo, S. (2010) *An introduction to science and technology studies* (2nd ed.). Chichester, West Sussex: Wiley-Blackwell.

Sjöberg, L. (2009) Precautionary attitudes and the acceptance of a local nuclear waste repository. *Safety Science, 47*(4), 542-546.

SKB (2007) *RD&D Programme 2007 - Programme for research, development and demonstration of methods for the management and disposal of nuclear waste.* Retrieved 0214, 2019, from http://www.skb.se/publikation/1578457/TR-07-12.pdf

SKB (2011a) *ANSÖKAN OM TILLSTÅND ENLIGT LAGEN OM KÄRNTEKNISK VERKSAMHET*. Retrieved 1112, 2020, from https://skb.se/wp-content/uploads/2015/05/flik_01a.pdf

SKB (2011b) *ANSÖKAN OM TILLSTÅND ENLIGT MILJÖBALKEN*. Retrieved 1112, 2020, from https://skb.se/wp-content/uploads/2015/05/flik_01a1.pdf

SKB (2013a) *Fud-program 2013 - Program för forskning, utveckling och demonstration av metoder för hantering och slutförvaring av kärnavfall.* Retrieved 0208, 2016, from http://skb.se/upload/publications/pdf/Fud_2013.pdf

SKB (2013b) *RD&D Programme 2013 - Programme for research, development and demonstration of methods for the management and disposal of nuclear waste.* Retrieved 02-14, 2016, from http://www.skb.se/publikation/2670359/TR-13-18.pdf

SKB International (2020) *Nuclear Waste is our Business.* Retrieved 0924, 2020, from https://www.skbinternational.se/

Socialdemokraterna (2022) *Kärnkraft: En viktig del av svensk elproduktion.* Retrieved 0830, 2022, from https://www.socialdemokraterna.se/var-politik/a-till-o/karnkraft

Solomon, B. (2009) High-level radioactive waste management in the USA. *Journal of Risk Research,* 12(7-8), 1009-1024.

Solomon, B., Andrén, M. & Strandberg, U. (2010). Three decades of social science research on high-level nuclear waste: Achievements and future challenges. *Risk, Hazards & Crisis In Public Policy,* 1(4), 13-47.

Soneryd, L. (2016) Technologies of participation and the making of technologized futures In: *Remaking participation: science, environment and emergent publics.* (Eds.) Chilvers, J. & Kearnes, M. Abingdon, Oxon: Routledge, 144-161.

Sundqvist, G. (2002) *The bedrock of opinion: science, technology and society in the siting of high-level nuclear waste*. Dordrecht: Boston, Kluwer Academic Publishers.

Sundqvist, G. (2014) 'Heating up' or 'Cooling Down'? Analysing and Performing Broadened Participation in Technoscientific Conflicts. *Environment and Planning. A,* 46(9), 2065-2079.

Sundqvist, G. & Elam, M. (2009) Sociologin, hybriderna och den sociala verkligheten - Exemplet kärnavfall. *Sociologisk Forskning,* 46(2), 4-25.

Sundqvist, G. & Elam, M. (2010). Public Involvement Designed to Circumvent Public Concern? The "Participatory Turn" in European Nuclear Activities. *Risk; Hazards And Crisis In Public Policy,* 1(4), 1-27.

Svačina, K. (2017). How (not) to talk about the uncertain: Siting geological disposal for highly radioactive waste in the Czech Republic. *Journal of Risk Research,* 20(9), 1211-1225.

SVT (2021) *Kommunalrådets krav till Löfven – tidplan för slutförvar av kärnbränsleavfall.* Retrieved 0503, 2021, from https://www.svt.se/nyheter/lokalt/smaland/kommunalradet-skickar-brev-till-lofven-kraver-tidplan-pa-slutforvar-av-karnbransleavfall

Swedish Research Council (2017) *Good Research Practice.* Retrieved 0220, 2023, from https://www.vr.se/analys/rapporter/vara-rapporter/2017-08-29-god-forskningssed.html

Söderberg, J. (2017) The Genealogy of "Empirical Post-Structuralist" STS, Retold in Two Conjunctures: The Legacy of Hegel and Althusser. *Science As Culture,* 26(2), 185-208.

Taebi, B. (2012) Multinational Nuclear Waste Repositories and Their Complex Issues of Justice. *Ethics, Policy & Environment,* 15(1), 57-62.

Tryckfrihetsförordning 1949:105 (1949) *Tryckfrihetsförordning* (1949:105).

Vedung, E. (1979) *Kärnkraften och regeringen Fälldins fall.* Stockholm: Rabén & Sjögren.

Vilhunen, T., Kojo, M., Litmanen, T. & Taebi, B. (**2022**). Perceptions of justice influencing community acceptance of spent nuclear fuel disposal. A case study in two Finnish nuclear communities. *Journal of Risk Research,* 25(8), 1023-1046.

Walsh, E. (1981). Resource Mobilization and Citizen Protest in Communities around Three Mile Island. *Social Problems,* 29(1), 1-21.

Walters, D. (2013) *The Socialist Case for Nuclear Energy.* Retrieved 1207, 2021, from https://thebreakthrough.org/issues/energy/the-socialist-case-for-nuclear-energy

Weart, S. R. (2009) *Nuclear fear: A history of images.* Cambridge: Harvard University Press.

Wolsink, M. & Devilee, J. (2009) The motives for accepting or rejecting waste infrastructure facilities. Shifting the focus from the planners' perspective to fairness and community commitment, *Journal of Environmental Planning and Management*, 52(2), 217-236.

WP5 (2014) *Effectively engaging local citizen stakeholders in R&D/RD&D on monitoring for geological disposal.* Retrieved 0418, 2023, from http://www.modern2020.eu/activities/wp5-local-stakeholders-engagement.html

Wynne, B. (1982*) Rationality and ritual: The Windscale inquiry and nuclear decision in Britain*. Chalfont St Giles, Bucks: The British Society for the History of Science.

Martin, B. and Richards, E. (1995) Scientific knowledge, controversy, and public decision making, in: *Handbook of Science and Technology Studies* (Eds.) S. Jasanoff, G. E. Markle, J. C. Peterson and T. Pinch. London: Sage.