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BY
JAQUELINE DE GODOY

DISSERTATION SUBMITTED 2022

AALBORG UNIVERSITY
DENMARK

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CV

Jaqueline de Godoy is an Environmental Engineer from the Franciscan University in Brazil. She holds a master's degree in science communication from the Manchester Metropolitan University in the United Kingdom. Jaqueline began her PhD studies at the Aalborg University in 2018 as part of the Innovative Training Network as a Marie Curie Fellow of the Energy Systems in Transition Project (ENSYSTRA). Her research interests include socio-technical sustainable transitions, complexity and systems thinking, behaviour and cultures, posthumanism, sociology of scientific knowledge, and the development of an interdisciplinary mindset. In her dissertation, she investigates the energy experts´ practices when transitioning towards sustainable systems, proposing the concept of "energy habitus" for rethinking the energy expert´ methods, narratives, and approaches to mitigate anthropogenic climate change. Jaqueline continued developing an interdisciplinary profile in the ENSYSTRA project. The training and experiences broadened her understanding of the complexities of the energy transition and the importance of energy experts´ ethical decisions. During the project, she cooperated with researchers from diverse disciplines resulting in the preparation of eight publications, and coordinated and wrote the "Best practice guidelines for model collaboration" deliverable submitted to the European Commission. She also served as the early-stage researchers representative for 11 months, learning several administrative skills. Furthermore, during the PhD, she had research stages in academic and industrial organizations (University of Stavanger, Gothenburg University, University of Groningen, University of Graz, and a Norwegian utility company).

ENGLISH SUMMARY

This thesis presents accounts of energy experts´ **narratives for sustainable energy transitions** in the **North Sea Region**. The energy experts this work is focused on are energy researchers, policy makers, and industry energy experts, the latter including entrepreneurs, project managers, and company employees. I focus on energy experts because they are key stakeholders in socio-technical energy systems, and are strategically positioned to make decisions and drive changes for sustainable energy transitions. Energy experts are underexplored in transition studies however, they have to deal with highly complex scenarios that transcend technological solutions because these scenarios are centred in socio-technical contexts where technologies and energy experts' behaviour are co-dependent factors that enable futures for energy systems. Since the roles, responsibilities and consequences of experts' behaviour have been insufficiently researched, this thesis endeavours to fill this need by reporting on the narratives and perceptions of energy experts over sustainable energy transitions. This work started with this hypothesis: since experts are key stakeholders that shape how society orients itself during times of change, guiding energy experts´ decision-making in sustainable energy transitions requires a better understanding of other´s energy culture and one´s own. To investigate this, I applied a posthumanist lens to examine energy experts' narratives and focus on the nature of material-cultural processes and intra-actions.

The thesis is structured into two parts. The first part focuses on the energy expert's subjective experiences and the second on the cultures on socio-technical energy configurations. The chapters keep a close relation to five research articles prepared or already published during my PhD studies. Articles underlying part one include: "**Reflection through diffraction: Interdisciplinary in energy science**"**,** which explores the challenges of employing interdisciplinary approaches in energy research, and offers a framework to co-construct knowledge and facilitate collaborative practices between researchers in the energy sector. "**Energy transition innovators´ perceptions of the environment**". The article presents energy experts' narratives on

anthropogenic futures and their perceptions of the place they inhabit. Articles underlying part two are: "**Getting fair institutional conditions for district heating consumers: insights from Denmark and Sweden**", which exposes the challenges of achieving institutional conditions which protect customers of district heating systems. "**Expert´s perceptions of the role of district heating systems: Unveiling the cases of Sweden and Denmark"**, presents the role trust plays in socio-technical energy systems focusing on district heating in Denmark and Sweden as use cases. "**Transformations of trust in society: A systematic review of how access to big data in energy systems challenges Scandinavian culture"** presents the risks, opportunities, and proposals for the energy transitioning process given the increased digitalization of the energy grid. The thesis also includes two book reviews by the philosophers Bruno Latour (Down to Earth: Politics in the New Climatic Regime) and Shoshana Zuboff (The Age of Surveillance Capitalism. The Fight for a Human Future: at the New Frontier of Power). Both provided foundational theoretical ideas used in this work.

In this thesis, I contribute to understanding energy experts in relation to the energy transition in two ways. First, by identifying and analyzing the energy experts' perceptions of the environment, products, and processes while expanding the understanding of the energy experts´ situatedness about their energy culture. I propose that a successful transitioning process needs to start with an awareness of the energy experts' nested and subjective understandings of their roles and responsibilities. Then, to encourage them to be reflective about their own energy habitus so that they will be able to contribute to the transformation of energy systems from the core ideas embedded in today´s Anthropocentric societies. By focusing on the narratives that shape the sustainable energy transitions, this work acknowledges the existence of values, norms and practices in shaping energy systems. Second, the thesis contributes to detailing specific energy cultures constituted in the North Sea Region and proposes key considerations that are needed for the decarbonization of the energy sector while taking into account ethics and justice principles.

Keywords: energy cultures; narratives; experts; perceptions; sustainable energy transitions; socio-technical energy systems; roles; energy habitus; and responsibility.

DANSK RESUMÉ

Denne afhandling præsenterer aktørberetninger omkring narrativer for bæredygtige energiomstillinger i Nordsøregionen. De energiaktørerne der fokuseres på, omfatter energiforskere og energieksperter fra industrien, inklusive entreprenører, projektledere og ansatte i virksomheder. Der fokuseres på disse aktører da de hidtil kun er blevet undersøgt meget begrænset i energiomstillingsstudier, selvom de er nøgleinteressenter i forhold til sociotekniske energisystemer og er positioneret strategisk i forhold til at foretage beslutninger og drive forandringer vedrørende bæredygtig energiomstilling. Dette betyder, at de skal involveres i komplekse aspekter, der går ud over de rent teknologiske løsninger, eftersom de er centrerede i sociotekniske systemer, hvor teknologier og aktører er indbyrdes afhængige faktorer, der skaber nye muligheder for energisystemer. Idet roller, ansvarsfordeling og konsekvenser i forhold til aktørernes adfærd kun er undersøgt i utilstrækkelig grad, undersøger jeg disse områder i min afhandling med særligt fokus på ekspertaktørernes beslutningsprocesser. Min hypotese er, at bæredygtig energiomstilling kræver en bedre forståelse for såvel ens egen som andres energikultur for at kunne guide eksperternes beslutningsprocesser, eftersom de er nøgleinteressenter og påvirker forbrugernes orientering i forbindelse med omstillingsprocesser. Derfor har jeg i min teoretiske undersøgelse af energiaktørernes narrativer i forhold til deres roller og ansvarsområder med hensyn til påvirkningen af normer, praksisser og materialiteter relateret til energiomstilling anvendt en posthumanistisk linse i en socioteknisk systemkontekst. Afhandlingen er todelt; den Første del fokuserer på aktørerne og den anden del på sociotekniske konfigurationer. Afhandlingen inkluderer seks forskningsartikler. Del et inkluderer: "**Reflection through diffraction: Interdisciplinary in energy science**"**,** hvor udfordringer ved at anvende tværfaglige forskningstilgange undersøges, og der skabes en struktur til samskabning af viden og facilitering af e kollaborative praksisser blandt forskere inden for energisektoren. "**Energy transition inovators´perceptions of the environment**". I afhandlingens anden del præsenteres risikoer, muligheder og forslag til transitionsprocesserne gennem øget digitalisering af energinet i: "**Transformations of trust in society: a**

systematic review of how access to big data in energy systems challenges Scandinavian culture". Paperet "**Getting fair institutional conditions for district heating consumers: Insights from Denmark and Sweden**" afdækker udfordringer i forbindelse med opnåelse af fair institutionelle samfundsmæssige forhold i forbindelse med fjernvarmesystemer. Slutteligt beskriver "**Expert´s Perceptions of the role of district heating systems: Unveilling the cases of Sweden and Denmark"** den rolle tillid spiller i sociotekniske energisystemer med fokus på fjernvarme i Danmark og Sverige. Afhandlingen inkluderer også to boganmeldelser relateret til fundanmentale teoretiske ideer anvendt i dette arbejde af filosofferne Bruno Latour (Down to Earth: Politics in the New Climatic Regime) og Shoshana Zuboff (The Age of Surveillance Capitalism. The Fight for a Human Future: at the New Frontier of Power).

Denne afhandling bidrager til forståelse for energiaktører relateret til energiomstillingen på to måder. For det første afklares aktørernes opfattelse af miljøet, produkter og processer i forhold til forankringen i ekspertkulturen på energiområdet. En vellykeet transitionsproces skal starte med at have opmærksomhed på energiaktørernes indlejrede og subjektive forståelser af deres roller og ansvarsområder, og med at de reflekterer over deres egen energihabitus og dermed bliver i stand til at bidrage til transformationen af energisystemer på vegne af borgerne. Dette arbejde anerkender eksistensen af værdier, normer og praksisser, og fokusserer på, hvordan narrativerne udvikler bæredygtig energiomstilling. For det andet bidrager afhandlingen med en mere præcis beskrivelse af specifikke etablerede energikulturer i Nordsøregionen og kommer med foreslag til nøgleovervejelser omkring de nødvendige tiltag, der skal til for at accelerere afcaboniseringen af energisektioneren, men samtidig anerkende aspekter som etik og ret færdighed, når nye energisystemer skal skabes.

Keywords: energy cultures; narratives; perceptions environment; socio-technical energy systems; roles; energy habitus; and responsibility.

PREFACE: THE TRAJECTORY OF MY SOUL

I was born in a country that, despite having an abundance of renewable resources to produce energy, remains the ninth[1] country in terms of daily extraction and production of fossil fuels. In the context of the Brazilian energy culture, my understanding of energy matters emerges as a result of an embodied experience. My engineering background was centred on designing apparatuses for problem-solving, centred on a limited view of what entails the material things in the world. This contributed to a mindset and concerns regarding energy systems based on a technocratic view of society. However, my interdisciplinary career allowed me to amplify my understanding of the complexities of energy-society matters and the environmental impact of enormous power plants. Like the Itaipu hydropower plant in the state of Parana-Brazil, a place I have visited sometimes on family trips and technical fieldwork. The richness of the environmental engineering background allows me to have engineering skills grounded in technological comprehension, about techniques and tools, and an understanding of the dynamics of processes on Earth. The PhD was fruitful in exploring posthumanist theories, deepening my understanding of ethico-onto-epistemological matters in relation to apparatus, humans, and the "*relationship between them*" (Barad, 2007 p. 145, my emphasis). Altogether, I could explore in this thesis the energy culture which is conformed by apparatuses, technologies, techniques, economies, society, resources, experts, behaviour, and all the components that must be considered as a whole (as every culture, according to Jacques Ellul (2021)). However, exploring energy cultures striving for an interdisciplinary, integrated, and worldwide perspective is an achievement of my entire life´s work and is very complex for a nascent researcher like I am.

My embodied experience was further complemented by the significance of land in the Brazilian culture—mainly dedicated to agriculture and having a strongly hierarchical

[1]According to https://www.worldometers.info/oil/brazil-oil/ retrieved on 06 September 2021.

and dominant relationship with the environment, nature, and animals. This view was further reinforced during my training as an engineer when I knew little about the nested hierarchy in regimes and power imbalance among humans, and between human and non-human beings regarding energy resources. At that time, energy was too abstract or too much of an engineering concept to me. However, during my career, my instinct and pressure from a gender-imposed experience reinforce the idea that the engineering knowledge and methods taught within the engineering curriculum were too narrow with respect to the wholeness of what it means to live in the dynamic environment emerging from the interaction between society and engineering. By being narrow, traditional engineering frameworks minimize the need for deep reflections on power imbalances and ethical implications of technical developments for societies. In this thesis, I deepened an understanding of society, environment, and engineering dynamics that create and propagate inequalities. I am grateful to scholars and philosophers whose theoretical frameworks contributed to understanding sociomaterialities as intertwined, illuminating my inquiries.

Exploring the frontiers of knowledge in fields related to social science opened my mind with respect to three aspects in particular: 1) Mono-disciplinary perspectives are limited in achieving just energy transitions. 2) Responsibility as an engineer entails incorporating justice principles to deal with the power of infrastructures and technologies, as well as considering ethico-onto-epistemic entanglement in relation to infrastructures and technologies. 3) Social structures are an act of performance. Thereby, the democratization of social infrastructures must be prioritized. With all this in mind, I wish to dedicate my life to tackling climate change injustices, gender imbalance matters, and power struggles related to socio-technical infrastructures.

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To the family, thank you for being a source of motivation to develop the best version I can be. Mom, thank you for all. Gabriel, words lack the meaning of our sharing. Thank you. To my friends for life, Kirsten, Thyge, Brigitte, Alisson, Helo, Marcio, Georgia, Iuri, Bruna, Juline, Drieli, Ashish, Bianca. To the non-human actors always shaping my being. The opportunity to undertake doctoral research was thanks to the professors who envision the ENSYSTRA project and the economic support received from the European Union's Horizon 2020 Research and Innovation Programme under the Marie Skłodowska- Curie grant agreement number 765515. Thank you!

Jaqueline de Godoy

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ACRONYMS

AAU Aalborg University

ANT Actor-Network Theory

ENSYSTRA Energy Systems in Transition

EPA Environmental Protection Agency

ESRs Early Stage Researchers

EGR Emissions Gap Report

DH District Heating

DSOs Distribution System Operators

GGE Greenhouse Gas Emissions

IEA International Energy Agency

IRENA International Renewable Energy Agency

IPCC Intergovernmental Panel of Climate Change

NGOs Non-Governmental Organizations

NMB Network Management Board

NSR North Sea Region

MLP Multi-Level Perspective

REA Research Executive Agency

SC Surveillance Capitalism

STS Science Technology and Society

SCOT Social Construction of Technology

SDGs Sustainable Development Goals

UNFCCC United Nations Framework Convention of Climate Change

UNEP United Nations Environmental Programme

WTO World Trade Organizations

OVERVIEW OF DISSERTATION

This dissertation is supported by seven published, accepted or submitted articles and review articles listed below.

Part 1: Energy experts´ subjective experiences

A. Godoy, J., Otrel-Cass, K., Gorroño-Albizu, L., and Yang, J. (2022). Reflection through Diffraction: Interdisciplinarity in Energy Science. *Knowledge Cultures* 10(2): 95–122. https://doi.org/10.22381/kc10220225

B. Godoy, J. (2020). Book Review: Down to Earth: Politics in the New Climatic Regime. *Frontiers in Climate*, 2, 1-3 https://doi.org/10.3389/fclim.2020.524365

C. Godoy, J. (2022). Energy transition innovators´ perceptions of the environment. (article in preparation)

Part 2: Cultures on socio-technical energy systems

D. Gorroño-Albizu, L., & Godoy, J. (2021). Getting fair institutional conditions for district heating consumers: Insights from Denmark and Sweden. *Energy*, 121615. https://doi.org/10.1016/j.energy.2021.121615

E. Godoy, J., Gorroño-Albizu, L. (2022). Experts' Perceptions of the Role of Trust in District Heating Systems: Unveiling the Cases of Sweden and Denmark. (article in preparation)

F. Mannov, A., Andersen, A. O. & Godoy, J. D. (2020). Review: The Age of Surveillance Capitalism. The Fight for a Human Future: at the New Frontier of Power. *In: Tecnoscienza: Italian Journal of Science & Technology Studies* 11, 1 p. 109-113 http://www.tecnoscienza.net/index.php/tsj/article/view/434/262

G. de Godoy, J., Otrel-Cass, K., & Toft, K. H. (2021). Transformations of trust in society: a systematic review of how access to big data in energy systems challenges Scandinavian culture. *Energy and AI*, 100079. https://doi.org/10.1016/j.egyai.2021.100079

CHAPTER 1. INTRODUCTION

This thesis is entitled *Unprecedented times: understanding narratives for sustainable energy transitions* with the aim of unraveling what energy cultures are emerging out of the energy transition, as well as how the different experts act on the transformation of energy cultures in the context of the North Sea Region (NSR). I examine the existing, emergent, and required narratives on sustainable energy transitions by exploring several knowledge sources to identify expected and unexpected patterns. The research is centred on improving understanding of how energy experts are driving the developments of energy systems. I look at projects on sustainable energy transition since these can be seized as an opportunity to examine different energy experts' views regarding society-technology-energy matters and understand the experts´ drivers and barriers when shaping energy transitions. The focus on energy experts is because the nature of the climate change problem is partially a consequence of our, and energy experts´ perception of energy. Thus, solving the climate crisis requires rethinking the underlying centrality of humans needs present in our perception of energy systems.

Human actions, perceptions and thoughts are shaped by their habitus and shape their social practices (Bourdieu, 1994). Yet, little is investigated about energy experts' reflective abilities about their own habitus (Bourdieu, 1990) or about the power that their roles in the energy transition carry. My underlying assumption is that investigating energy experts' actions and practices can reveal areas where the lack of reflection on their habitus can hamper the best solutions for the energy transition.

With the energy transition taking place, the decisions experts are making on a daily basis become routinized practices, according to the experts´ preferences and world views, consequently becoming normative on the systems they affect (Mendoza et al., 2012). Paradoxically, the energy transition requires reimagining social structures, systems of beliefs, roles and cultures of energy (Clarke, 2015; Valtonen et al., 2020), here, the concept of habitus as described by Pierre Bourdieu (2018) allows us to account for people’s present actions and practices, and their resulting regularities as a product of their past.

Energy experts´ practices constitute a central inquiry of this thesis. However, since the projects on energy transitions occur with the mutual shaping of socio and technical elements (socio-technical systems (Leonardi, 2012)), it is not enough to only investigate the accounts of energy experts, but also the different materialisations of their practices. For this, posthumanism offers a set complementary theories also supporting this thesis, specifically important are the insights from agential realism theory and the diffractive methodology by Karen Barad (2003, 2007).

In what follows, this PhD research is situated by presenting the details of the problem statement, the research questions, the background, context, justification, adopted approach adopted and the structure of the manuscript.

1.1. PROBLEM STATEMENT: ENERGY EXPERTS IN THE ENERGY TRANSITION

Transitioning existing fossil-fuel-based energy systems into a 100% renewable energy grid opens up complexities that go beyond technological solutions. Those complexities are associated with political-ideological (Berg et al., 2021; Biggar & Magnus, 2020), institutional (Diesendorf & Elliston, 2018; Kainiemi et al., 2020) and cultural barriers (Diesendorf & Elliston, 2018; Ruotsalainen et al., 2017; Strauss et al., 2013). Energy professionals, researchers, entrepreneurs, project managers and coordinators manage those complexities and shape sustainable energy systems (Zohar et al., 2021). Individuals within these and similar roles are considered by society as `energy experts´. For instance, Peter Haas (1992) understands experts by defining an ´epistemic community` as a "network of professionals with recognized expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain or issue-area" (p. 3). Simillarly, Jacques Ellul (2015) posits that experts´ real influence is on politics and that they are agents who rationalise their decisions and define systems (e.g. socio-technical configurations) in the form of institutions and innovations. This can be understood as materialization of their practices, which in turn, drive rules and programs for society.

It becomes clear that lack of understanding about the culture of `energy experts´ who underly sustainable energy transitions can leave the decision on the future of energy

systems in the hands of a few who are not necessarily well equipped with the principles of fairness, justice, and adequated views on the community needs. Understanding energy experts perceptions of energy is not just relevant because they are "enablers of the transition" (Zohar et al., 2021 p. 1), but also because they are strategically positioned in social networks[2] (Parag & Janda, 2010), enabling action, inaction, change, and stagnation of projects (Zohar et al., 2021). Thus, examining how energy experts manage the energy transition and make their decisions is an inquiry that deserves closer attention. In the words of Karen Barad, "we are responsible for the world within which we live [...] because it is sedimented out of particular practices that we have a role in shaping" (Barad, 2007 p. 203). In this thesis, I specifically explore the practices of energy experts in the context of the NSR and the Energy Systems in Transitions (ENSYSTRA) project[3]. Those experts are in a position to shape practices on knowledge production (chapter 4), the way environment and natural resources are used (chapter 5), cultural aspects on institutions and regulations (chapters 6 and 7), transformations energy-society relations (chapter 7) while managing energy resources, and solving problems of socio-technical nature and complexity.

I consider that energy experts have an "agentive participation" (Barad, 2007 p. 207) in the process of transforming matters of energy-society-technologies. Implying that, according to the agential realism theory, experts' practices are not seen on "effects or consequences of discursive practices" as in postmodern feminism and poststructuralist theories; instead, energy experts' practices are phenomena co-constituted by the entanglement of materialities and discourses into the practices (Barad, 2007 p. 225). Thus, energy experts' influence and perceptions are as relevant as their surroundings and environment influence the experts. It is important to consider that in the process

[2] The term ´network` here is based on the description in actor-network theory, where it is used as an "attempt to describing societies" and what holds society together by looking at for example the "facts manufactured by natural and social science and the artefacts designed by engineers" (Latour, 1996 p. 370).

[3] Energy experts cultures are heavely context dependent. Thus, some of the results cannot simply be extrapolated to all communities. Nonetheless, the methods hereby introduced can advance further research to explore energy cultures from other communities, regions, and socio-technical systems.

of transformation of energy-society-technology matters, specific characteristics of culture and nature are not seen in this thesis as playing an external or passive role in influencing sustainable energy systems. Instead, they should be seen as entangled with practices. Such consideration puts our attention on the energy experts´ drivers and inhibitors, both human and non-human, providing new insights on energy experts´ modes of action, as well as on factors influencing how experts engage, how their actions relate to each other, interrelate and co-evolve (Parag & Janda, 2010; Wittmayer et al., 2017). Insights that align stakeholders´ visions with the narratives needed to transition to sustainable energy systems are can support strategies and policy design (Ford & Hardy, 2020). Furthermore, considering the practices of experts as intra-acting[4] in the process of what the energy systems are becoming, amplifies the awareness of how much we can influence the surroundings we are part of (Barad, 2007).

With the context above, I expose how understanding energy experts' perceptions could provide insights into their roles and responsibilities in shaping sustainable energy transitions. The reader will find in the results (part 1 and part 2), my exposition shows the energy experts' narratives, how they are culturally acquired and transformed into practices, and are at times self-perpetuating energy cultures for society. They are as well evidence of the influence of moral values, ethical perspectives, fair practices, and energy justice principles that inform the energy experts´ performances.

Therefore, to unravel the energy cultures emerging out of the energy transition in the NSR, this thesis analyses energy experts´ nested cultures, narratives, and moral values to allude energy experts to shaping fair energy systems.

1.1.1. RESEARCH QUESTIONS

The overall question that guides this research is:

[4] Baradian nomenclature that contrast interaction. In interaction separate agencies preceed their interactions. Intra-action in other side assume distinct agencies do not preceed, but emerge through (Barad, 2007).

What role do energy experts' perceptions of the environment, their products, and processes play in the transformation towards sustainable energy systems?

This question is answered by exploring the following sub-questions:

1. How do energy experts' energy cultures shape their perceptions, practices, and products for sustainable transitions?
2. What (new) theoretical narratives and methods emerge from energy experts that support the sustainability of energy systems?
3. How do energy experts´ ethical perspectives (fairness, trust, morals, power) shape the energy transition process?

The outcome of this research is a deeper understanding of the energy cultures that energy experts are immersed in and of the cultures they are pursuing (intentionally or unconsciously). This was achieved by deriving insights, via a multi-method approach, into the role of the perception of the environment, products and processes on shaping those energy cultures around energy systems. The qualitative data analysis enabled me to understand the narratives on sustainable energy transitions and map the theoretical narratives needed to support sustainable energy transitions. In the final chapters, I emphasise the emerging and needed ethical perspectives for inducing fairer or more just energy systems and actions contextualized for the environment, the societies of the NSR and the impact of the decisions for both this region and the globe. Since the transition to socio-technical energy systems is a consequence of our increasing understanding of the anthropogenic causes of the climate crisis, I continue by presenting in the following section the complexities of humans dealing with climate change. Such complexities define the background for understanding energy experts´ practices.

1.2. BACKGROUND: ANTHROPOGENIC CLIMATE CHANGE, COMPLEXITY AND ENERGY TRANSITION

1.2.1. ANTHROPOGENIC CLIMATE CHANGE

The title of this thesis, *unprecedented times,* is inspired by its use for the first time in the Sixth Assessment Report of the United Nations - IPCC (IPCC, 2021 p. 7), to

emphasize the rapid global temperature increase, with an urgent call to mitigate the impact of climate change on ecosystems. Scientific evidence report that the effects of anthropogenic climate change have increased dramatically since the 1970s compared to any previous period in the last 2000 years (IPCC, 2021). Therefore, efforts to end Greenhouse Gas Emissions (GGE) are required from all countries and societal sectors. Aligned with this problematic, the European Union (EU) has agreed to be zero GGE emissions by 2050. Such emissions not only refer to those mostly prevenient mainly from carbon dioxide (CO_2), but also from methane (CH_4), nitrous oxide (N_2O), and fluorinated gases (F-gases) (Environmental Protection Agency (EPA), 2021).

Limiting the cumulative GGE is imperative so that the global surface temperature stays below 2°C above preindustrial levels. The current target is to limit emissions to produce a maximum of 1.5°C above preindustrial levels (IPCC, 2018). However, in the last report, the narratives regarding this aspect changed: “global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades” (IPCC, 2021 p. 17). This alarming realization occurred in three years due to the still increasing global use of fossil fuels (Ritchie & Roser, 2017) with the consequent raising of CO_2 emissions (Figure 1). Experts on the IPCC (2021) reported with high confidence that the consequences of failing to reduce the emissions to net-zero by 2050 are that the earth's temperature will keep increasing, having impacts on: the health of humans and of all species, the occurrence of more weather and climate extremes (heat and cold waves, heavier precipitation events), on the oceans (sea-level rise, marine heatwaves, lower levels of oxygen in regions, temperature and acidification of oceans), and on the land biosphere (land evapotranspiration and habitat loss).

Even knowing full well the consequence and the with enormous attention, efforts and urgency for decarbonising, the progress in actions to globally reduce CO_2 emissions has been slow, thus, the emissions, are continuously increasing. One of the problems is that such increase prolongs the exposure of humans in the most vulnerable conditions to the climate change threats, which impacts are already disproportionate by affecting society (Thomas et al., 2019). Consequently, creating even more social

stratification in societies (marginalizing mainly women, children, and older people) (Levy & Patz, 2015). Hence, there is a greater need for social injustice to be adequately addressed in mitigating policies (Markkanen & Anger-Kraavi, 2019). Crucial to avoid violations of human rights to life, physical security, subsistence and health (Bell, 2011), as well as rights of other species and the environment.

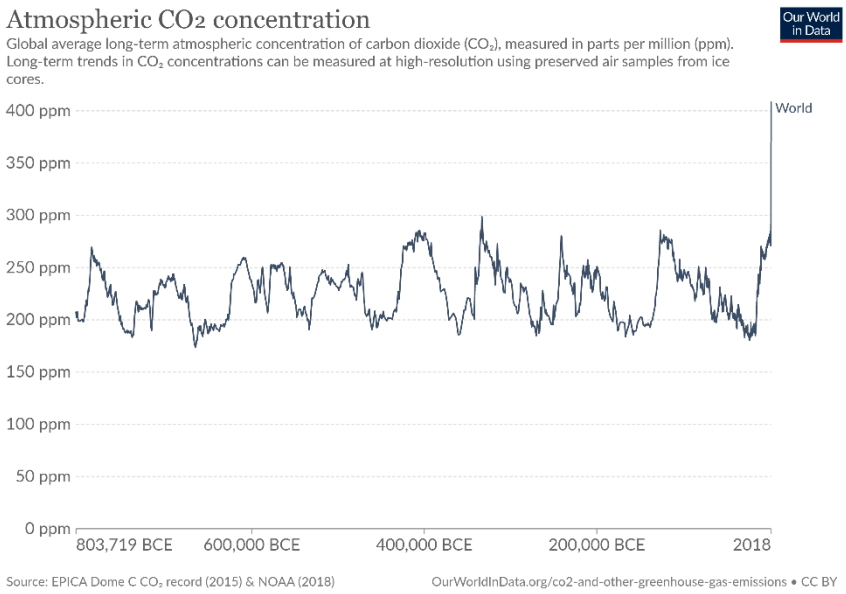

Figure 1. Evolution of the atmospheric CO_2 concentration (Ritchie & Roser, 2017).

With all this in mind, my hypothesizes is that mastering how energy experts perceive the consequences, mitigation and adaptation actions for the climate crisis contributes to understanding why reducing such greenhouse gas emissions is so complex. Parallel critical questions that underlie this research are: how does the experts' behavior influences discourse lock-in and carbon-lock in, and how does it delay or create path dependency on emissions reductions? What is the socio-cultural context that those experts are embedded in when shaping their perceptions of the climate crisis? How do the methods and skills that experts are equipped with advance in reconstructing existing modes of engaging with energy resources? Finally, how does the role and responsibility for reducing emissions come down to the views of energy experts who

may, or not be, well equipped with moral values and ethical principles to address the complexity of the crisis? To dive deeply into those questions, I continue by presenting below some of the social complexities associated with cutting GGE.

1.2.2. WHY IS REDUCING GGE COMPLEX

The urgency of the crisis motivated the Paris Agreement, active since 5 October 2016, it was the first global and legally binding climate agreement aimed at scaling up countries' efforts to reach net-zero emissions by 2050 (European Commission, 2015). However, climate policies are based on countries setting their own emission reduction targets, which can be driven by the willingness to cooperate (Falkner, 2016) or a national energy culture favouring ambitious carbon emissions reductions (Stephenson et al., 2021). Although those global climate agreements intend to drive nations' targets, they have shown to be insufficient to scale up reductions in GGE emissions (see, for instance, Sean O´Neill (2022) discussion on the long-term projections based on the Emissions Gap Report 2021 launched during the DP26 by the UNEP). National goals are reviewed and compared internationally to motivate countries' commitment to addressing the global crisis, but it is of national governments' responsibility to set those goals, and moreover, countries cannot be forced to commit to a global target[5] (Falkner, 2016). This creates inconsistencies between global needs and national contributions (Höhne et al., 2017). To deal with such discrepancies, emergent strategies are carbon market mechanisms and international carbon tax (such geopolitical affairs are discussed more in chapter 5) (O´Neill, 2022; Schneider & La Hoz Theuer, 2019).

The complexities associated with reducing GGE emissions increase the pressure in social, economic, and political spheres. Substantial research has been conducted to understand those complexities, to name a few: global geopolitics (Latour, 2018; O´Neill, 2022), business lobbying to maintain the status quo (Biresselioglu et al., 2020; Stephenson et al., 2021), influencing policies to delay coal phase-out (Brauers

[5] Neither to stay committed to the Paris Agreement, as evidenced by the United States withdrawing from the climate pact in 2020 (Tollefson, 2017).

et al., 2020) or greenwashing policies (Geerts et al., 2014), also, climate change deniers (Sovacool et al., 2020), power relations and imbalances (Avelino & Wittmayer, 2016), and organizational processes (transparency and trust issues, lack of technical resources, and experts skills) (Biresselioglu et al., 2020).

Structural obstacles rooted in the segregation between the global northern and southern hemispheres limit fair global agreements. Globally, climate change can be segregated between “experienced" and “imposed” effects (Sovacool et al., 2016 p.1), For example, the Global North (USA and EU-28) are responsible for most of the GGE emissions, accounting for 69% of the cumulative territorial emissions (in the period between 1850-2015) (Hickel, 2015). However, countries more vulnerable to the impacts of climate change and toxic pollution are those with the lowest income (Beck, 2008; Richard et al., 2021). Lowest-income and middle-income countries are responsible for 8% of the excess resources used, while consequences of global emissions are mostly felt in the global south such as Latin America, the Caribbean, Africa, and the Middle East (Hickel et al., 2022). Complexities as such, are one of the obstacles for climate agreements and for understanding the climate crisis as a matter of justice.

Since climate change triggers different effects, the perception of its urgency vary, increasing the complexity of taking effective actions. While in Scandinavia, people observe the summers becoming warmer, which can induce positive changes in socio/cultural activities, in the global south, extreme weather events affect food production, leading to starvation and civil conflicts (that I have witnessed firsthand)[6]. Even though we are all part of the same problem, socio-cultural contexts are unequal because societies' practices have a path dependency on historical factors. Yet, problems caused by climate change will make the future even more uncertain (Beck, 2008). So, how do disproportionate effects and responsibility influence people´s perceptions of the severity of the climate crisis?

[6] Similarly, I have evidenced experts working with the energy transition describing the effects of the climate change as long term effects, instead of a reality (see more in section 5.5).

Even though the last IPCC (2021) summary for policy-makers highlighted that it is imperative to make deep cuts in the GGE emissions, cutting emissions is not a simple task due to path dependencies of behavior and lock-in effects. High reduction in emissions require deep transitions to avoid irreversible consequences that risk the Earth´s biosphere and all species that depend on it (Schot & Kanger, 2018). However, considering the barriers and constraints to deep reductions in emissions, coordinating actions is not an easy task for experts and geopolitics.

Especially if constraints and specific challenges of decarbonization by sectors are to be considered. For example, in the energy sector, essential characteristics should be coordinated, related to environmental sustainability, security of supply, economic feasibility, and social and cultural adequacy of the strategies (Papadis & Tsatsaronis, 2020). As a general pattern, strategies pointed out as promising to decarbonize the energy sector rely on generating secondary energy sources, intervening in the end-use consumption behavior, and integrating sectors (e.g. water-energy nexus) (Papadis & Tsatsaronis, 2020). However, it is known that due to the complexity of restructuring energy systems, single-variable and reductionist approaches for the energy transition fail to achieve the results required for decarbonization.

An important phase in designing adequate strategies is understanding sub-cultures of distinct groups at a local level, which influence energy culture in society. This can reveal pathways to tackle weak points in the decision that can delay the decarbonization of the energy sector (Stephenson et al., 2021). For instance, obstacles to reaching social agreements about the actions to overcome the climate crisis can also be associated with the energy experts´ perceptions of the responsibility for the climate crisis, which influence which emissions are being accounted for, or not being accounted for or measured. For example, in the UK, Norway, Denmark, and the Netherlands, emissions from imports are considered as being indirect, for example, those from food and material goods, thus they are not included in national contributions despite representing two-thirds of the total emissions (Quirk et al., 2021). Conventionally the discussions about the reductions of GGE emissions follow the UN Framework Convention of Climate Change (UNFCCC), which measures the

country's impact based on the current territorial emission. However, this frame lacks the historical cumulative emissions that allow for the visualizing of country´s overshooting and undershooting, and for the allocation of responsibility according to a climate debt (Hickel, 2015; Matthews et al., 2014). Accounting for these cumulative emissions would be more consistent with principles of equal access to atmospheric commons, which helps differentiate the responsibilities on mitigating climate change while including ethical, equality and justice principles in the discussions of the climate change crisis (Hickel, 2015).

In view of all that has been mentioned so far, one may reflect that the complexity of climate change spans from the need to identify strategic solutions that provoke transformations in the core beliefs of societies and uncover the pathways to achieve GGE neutrality, as well as to adapt to uncertain climate variations (O´Reilly et al., 2020). For this, changing the perceptions of environmental responsibility can be a mediator in adjusting normative beliefs that can hamper environmental solutions (Wang & Lin, 2017). Furthermore, it requires those who have the power to influence the decarbonization decisions, i.e. the energy experts, to be equipped with principles of justice, trust, and a shared worldview (Latour, 2018; Parks & Roberts, 2008). In this way, climate change policies and societal innovations can adopt a narrative which changes the societal structures that create inequalities (for example, those gender-related (Djoudi et al., 2016)), by including voices that have been excluded when designing strategies for the climate crisis (Beck, 2008; Strauss et al., 2013).

Experts able to reflect on the climate problem with the overall understanding of the complexity of the effects and causes can change the perceptions about the responsibility for climate change towards a view driven by a sense of justice (Rawls, 1971), avoiding actions that keep propagating the climate crisis in the first place. John Rawls understands justice as fairness[7], coming from the equal opportunity principle. In practice, this means that it is the moral responsibility of those more fortunate to redistribute their benefits to the less fortunate (Said & Nurhayati, 2021). The

[7] The concept of fairness in relation to district heating was also explored in the chapter 7.

complexities of decisions about climate change adaptation and mitigation actions increase when there is a lack of a sense of responsibility and justice. This may impede implementing actions in energy systems that address power imbalances, climate change lobbing and other complexities mentioned above to be.

In the next section, the anthropogenic climate change and related complexities are discussed in the context of the way energy is used in contemporary societies and what this implies for the energy sector of the NSR.

1.2.3. THE ENERGY TRANSITION IN THE CONTEXT OF THE NORTH SEA REGION

Compared to other sectors, the energy sector in the NSR region represents the major source of CO_2 emissions (see figure 2), including the energy from all sectors, e.g. industry, transport and cooling and heating systems (Eurostat, 2020). Globally, the energy sector accounts for approximately three-quarters of the global greenhouse gas emissions, according to the International Energy Agency (IEA, 2021). Renewable energy accounts for only 18% of the power consumed in the Netherlands, Norway, Denmark, and the Netherlands (Quirk et al., 2021). The NSR is the wealthiest economic region in Europe, with the busiest marine area centered on oil and gas extraction, fishing, and marine traffic, due to the ports area, wind energy, and large offshore wind energy (Quante & Colijin, 2016). But, the reliability of non-renewable energy sources put the decarbonization of the energy and heating sector as a major concern for the NSR.

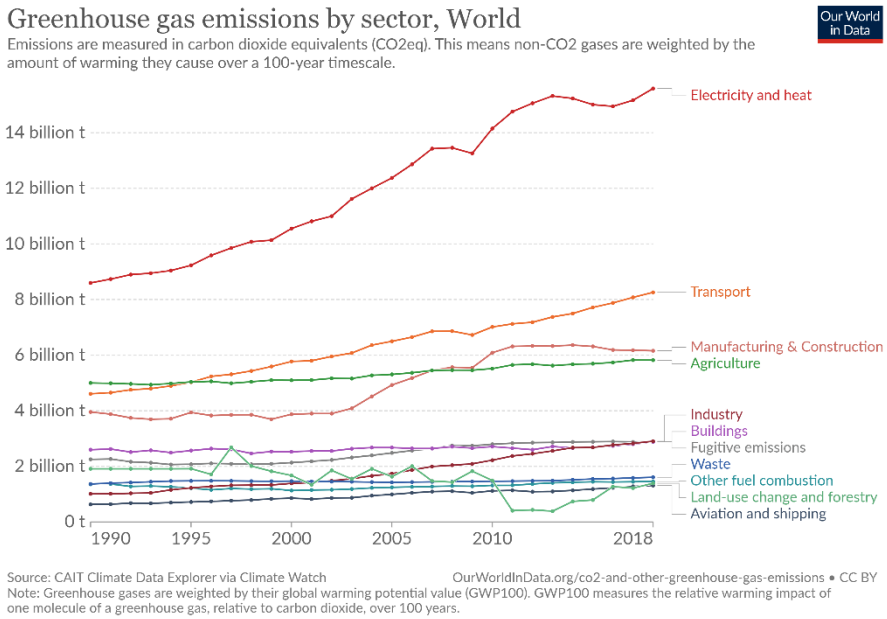

Figure 2. Greenhouse gas emissions by sector. Electricity and heat are the largest contributors to global emissions (Ritchie & Roser, 2018).

In the NSR, major consequences of climate change is environmental impact, such as an increase in the temperature and extreme sea-level rise, impacting the marine, coastal, lakes, and terrestrial ecosystems (Quante & Colijin, 2016). Reducing energy consumption by adopting more efficient lifestyles on the demand side and reducing emissions from burning fossil fuels on the supply side (IPCC, 2018) are strategies pointed out to reduce the climate change consequences. Furthermore, other feasible pathways to reduce emissions from the energy sector are electrifying transport systems (where possible) and increasing the share of energy produced by adopting renewable sources (IPCC, 2018). As renewable energy resources play a critical role in adaptation and mitigation responses to climate change (Jeong & Ko, 2021), the NSR region has been doing a great effort on expanding the range of solutions. Technologies already in operation and development in the region are 1. fixed-based and floating wind turbines, 2. high voltage direct current (HVDC) electricity cables, 3. recommissioned gas pipelines, 4. floating solar arrays, 5. tidal turbines, 6. electricity hubs, 7. wave energy converters, 8. carbon capture, 9. transport and offshore storage

(CCS) (Quirk et al., 2021). Furthermore, technologies available but not in operation or commercially available are 1. electricity hubs, 2. blue and green hydrogen production, 3. sub-surface storage of hydrogen, 4. geothermal energy from co-produced water and 5. carbon sequestration using marine biomass (aquaculture) (Quirk et al., 2021). Thus, it is expected that the future of the energy systems will include more diversity in the portfolios of energy sources, an increase in renewable energy sources and distributed energy grids (Skjølsvold & Lindkvist, 2015).

However, the challenges to cutting GGE emissions do not stop with developing greener infrastructure. Instead, key problems are related to coordinating many sectors (on the supply and demand sides), sector integration (relevance of district heating (DH) to the decarbonising energy sector is explored in chapter 6), and dealing with the intermittence of renewable energy sources (the use of big data analytics is explored in chapter 7). In general, the need of reconfiguring socio-cultural and socio-economic systems of norms and institutions that reproduce the climate change problems has been pointed out (Nielsen et al., 2021; Stoddard et al., 2021). Socio-technical, socio-cultural, and socio-economic reconfiguration deal with the challenge of changing current human beings worldviews, descriptive, and normative assumptions that each human has about the world they live in (Oostveen, 2020) and are based on high-carbon lifestyles (Stoddard et al., 2021). As a result, we and our cultural practices must transition to new ways of living, where justice is the underlying rule on the practices.

In the following section, I discuss how cultural practices related to energy in society can shape the energy transition.

1.3. ENERGY CULTURES SHAPING THE ENERGY TRANSITION

Societies are embedded in energy cultures and those energy cultures in turn shape societies. Exploring energy cultures can reveal the mutual interdependence of social and material elements and economic, political and environmental aspects (Pfister et al., 2017). Since energy cultures carry points of view on the functioning and order of systems, by studying them, we can unfold the dynamics of subjectivities, institutions, and infrastructures in energy systems (Pfister et al., 2017). Thus, studying energy

cultures is a key factor in understanding how societies organize their practices around energy and exploring the possibilities for societal change.

Here, attention must be given to the meaning of practices in a context where the objects of knowledge are constructed, but not as an objective reality in which the world reveals itself. In such a context, Pierre Bourdieu´s understanding of people´s habitus and their practices help to identify opportunities and constraints to influence the dynamics of energy cultures. According to Bourdieu, habitus is the embodied history of a person that manifests itself unconsciously, with an "infinite capacity of generating products ― thoughts, perceptions, expressions and actions" (Pierre Bourdieu, 1990 p. 55). A person´s habitus influences the practices on how they respond to external influences of the present; and shapes the reproduction of practices due to the "regularities immanent in the conditions in which their generative principle was produced" (Pierre Bourdieu, 1990 p. 56). Exploring Bourdieu´s concept of habitus in the context of energy practices should help reveal the reproduction processes of energy cultures through peoples´ habitus. For this reason, studying these ´regular` practices of energy experts (who carry the ´past` in the cognitive and motivating structures) can clarify the self-perpetuation of practices that produce energy cultures.

Energy cultures can be identified at different levels: internationally, nationally, locally, institutionally, and individually. However, for studying them, we can think of energy cultures in society as having social practices and collectively shared representations (Pfister et al., 2017). As a social practice, energy cultures are associated with electricity consumption and supply. Collective shared representations are the visions and shared notions of energy in society, which can be derived from the methods, theories, underlying assumptions and collective imaginaries about energy. However, the dynamics of influence of those layers are mutually shaped. As a whole, those factors characterize how society and energy are related, conforming to specific energy cultures.

This thesis focuses on critical factors that shape energy cultures in the context of Scandinavia. However, this work is not exploring energy usage and how the practices influence the demand. Instead, the main interest here is in the possible connections

between energy experts' subjectiveness, institutional characteristics, and socio-technical infrastructures. To better position the argument on how social practice may influence energy cultures, this topic is discussed in the following section.

1.3.1. ENERGY CULTURES IN SOCIAL PRACTICE

Social practices of energy use rely on understanding the behavior of citizens in their houses and communities when using energy. Individuals' daily decisions, practices and energy choices influence the intensity of carbon emissions. Individuals as part of societies have patterns of collective behavior shaped by societal norms and values (Buschmann & Oels, 2019). Those norms and values influence the practices, together with characteristics of technologies, scientific knowledge, infrastructures, processes, and resources, which all inform nested energy cultures. It is relevant to highlight is that citizens´ energy behavior influences energy planning decisions, not just in terms of energy efficiency and demand, but also as co-constructers of knowledge, influencing of political agendas, and changing energy system directions (Nikas et al., 2021; Shove & Walker, 2014). Overall, we can think that citizens' behavior influences energy cultures in society (with energy consumption behavior), as is also a driver for societal transformations (e.g. feasibility and desirability of energy projects (Nikas et al., 2021)). Citizens´ level of influence is increasing since customers are playing new roles in energy systems. Driving by significant changes in energy cultures in relation to emergent business models, where customers can be now prosumers, taking active positions as producers *and* consumers of energy (IPCC, 2018)).

Understanding society-energy practices as an energy culture is relatively new in the academic literature. However, the shared concern on the need for less polluting lifestyles leads to exploring societies' energy culture from diverse angles. Pierre Bourdieu´ work on practices and strategies to change habitus has inspired the development of practical frameworks to understand societal behavior in relation to energy systems (Stephenson, 2018). Energy cultures of citizens and communities is understood as the interplay of material cultures, practices, norms, and external influences (Stephenson et al., 2010; Stephenson et al., 2015). Material cultures are the technologies, structures, and artefacts, while practices are routinized and less frequent

activities. Meanwhile, norms are a set of shared beliefs about accepted and expected practices. Finally, external influences are factors beyond citizens and communities control that affect practices, actions, and material cultures (Stephenson et al., 2015). Changing energy cultures is complex because it depends on the interplay of citizens' behavior and the experts' decisions at a sector level. Thus, energy cultures can be maintained due to deep-rooted habitus from householders, government resistance to implementing adequate policies and regulations, and resistance from industry to give up the economic benefits provided for conventional energy sources. In Zambia for example, the application of the energy culture framework helped to identify that the persistence of using charcoal for cooking purposes requires efforts to improve the trust between electricity providers and customers, as well as government actions supporting the development of, e.g. mini-grid power generation technologies (Jürisoo et al., 2019). Thus, the comprehension of the energy cultures on the demand side is intimately linked to societal practices and inseparable from spatial, temporal, infrastructure, and institutional factors (Shove, 2017).

To fully grasp the energy cultures of society it is necessary to transcend the boundaries of energy use and supply practices. According to Janet Stephenson et al. (2015), the energy cultures framework, which was initially designed to understand energy cultures at a household level, can be applied to other environments and sectors (Stephenson, Hopkins, Doering, 2015). As a heuristic tool, it can support interdisciplinary communication and reveal emergent behavioral characteristics and actors' preferences that drive policies. See, for example, Stephenson, Hopkins, and Doering (2015), for an exploration of the regulations and strategies used to deal with the still-dominant energy supply culture around fossil fuels in the case of the transport transitions.

Globally, we can consider (in a simplified way) that historically we had a first deep transition marked by the oil energy culture becoming dominant in society. Then, the second deep transitions, from 1970 till nowadays, which relies mostly on dealing with the consequences of the oil culture that marked the first deep transition (Schot & Kanger, 2018). Recently, international organizations like IEA (2021) and the IPCC (2018) have been calling for accelerating the clean energy transition, adopting non-

polluting energy sources as well as less polluting lifestyles. This requires that countries reconfigure their energy cultures. According to Janet Stephenson et al. (2021), national energy cultures can be understood by the interplay of normative, material, institutional and policy-related factors (Stephenson et al., 2021). Speaking from a country standpoint this implies the existence of diverse energy cultures around the globe. For example, while in India, energy culture aim at guarantee energy security by adopting low-cost energy pathways, Denmark focuses on innovative low-carbon initiatives that promote social well-being. In China, energy works as an ally for economic progress (Stephenson et al., 2021). Similarly, Norway greatly relies on renewables (hydropower) to keep energy costs low (Biresselioglu et al., 2020). In this way, the context-wise studies are necessary to understand national energy cultures and design strategies that countries must adopt to comply with international agreements on GGE emissions reduction targets.

International, national, local, institutional, and individual energy cultures are part of the context that shapes energy experts' decision-making. Their decisions can be constrained by economic, technological, or cultural path dependencies derived from normative and historical choices. Those choices create expectations of what are acceptable policy responses creating constraints for actions, which can lead to a "self-perpetuating energy culture" (Stephenson et al., 2021 p. 4). Self-perpetuating energy cultures are also associated with the causal link between householders' demands and the national country's commitment to reducing carbon emissions (Stephenson et al., 2021). Therefore, aligning government actions with household energy cultures can result in lasting results in reducing energy-intensive consumption (Jürisoo et al., 2019). But, as we are dealing with complex systems, no formula exists to accommodate all the constraints. Neither do we have time for trial and error actions without severe damage from extreme events produced by climate change.

Undeniably energy experts' decisions entail several challenges, and although the consequences could be reduced by making non-polluting lifestyles a priority, in practice, this does not always happen. For example, preserving existing energy cultures has also been identified as an attempt by energy leaders and oil companies to maintain the status quo (as discussed in section 1.2.2). However, such energy cultures

benefit only a few people in society, where carbon lock-in and social inequalities are consequences for the others (Schot & Kanger, 2018). Bruno Latour (2018) pointed out that worldwide leaders adopted a posture of climate change deniers after realising that the land is claiming the resources back (see more in chapter 5). The way to restitute nature with all the damage caused to sustain unsustainable life standards is by changing our behavior and current societal energy cultures.

However, little energy research is concerned with knowing the influence of the energy culture on the experts' decisions and the role of energy experts in shaping energy cultures (Jasanoff & Kim, 2013; Ruotsalainen et al., 2017). Thinking from a cultural theory standpoint, culture is not seen as a homogenised characteristic. Instead, it comes down to the individuals who share common grounds (Lachapelle et al., 2014). Thus, energy experts´ decisions are likely influenced by the collective perceptions of the community they belong to and are surrounded by daily. As a result, experts' values, perceptions and cultures can impact their communities, even shaping institutions' energy cultures. Those can help move towards more ambitious emissions reductions at local and country-level goals. For instance, they can influence the behavior of citizens, provide recommendations for governments on policies and regulations for societies, and deal with energy planning, designing innovations, and implementing changes in energy systems (Parag & Janda, 2010). In this way, understanding energy experts individually, and as part of the energy culture provides insights into the underlying decision-making structures that energy experts influence.

Energy experts' responsibilities and roles are crucial for the energy transition. They can pave the way toward institutional conditions that enhance social acceptance of energy projects (Agterbosch et al., 2009). For example, Nordic countries' studies have identified high acceptability rates and minor opposition to energy projects. This has often been linked to the presence of trust in the institutions of those societies (see, for example, how trust influenced power lines development in Norway in Ceglarz et al. (2017)). This implies that those societies have perceived the actions of experts representing those institutions as trustworthy. Chapter 6 explores the perceptions of energy experts on the importance of aligning actions to societies' cultural traits in the development of energy systems (case study based on trust in DH systems). Alignment

of energy projects characteristics with the local culture can guarantee better social support from the community, advancing the development of socio-technical energy systems and environmental pro projects (IPCC, 2018). Research shows the importance of aligning social-political-institutional-economic contexts for social acceptance of new technologies. In carbon capture and storage (CCS) projects, for example, public trust in the stakeholders, industry and government, as well as the perception of the risks and benefits of the projects, were essential for projects development (Einsiedel et al., 2013; Orange et al., 2014).

Societies´ scepticism about experts' decisions can be reasonable considering the responsibility that energy experts carry: producing knowledge for the energy transition, dealing with changes and the problem of complex nature, coordinating the interaction between societal levels and groups, and pushing for low-carbon initiatives to meet international climate agreements (Falkner, 2016). Their power positions necessitate that energy experts be trustworthy; however, trusting experts in the absence of trustworthiness can put citizens in a risky situation (Hult, 2018). Experts can follow their agendas and preferences, influencing the decisions according to their interests, leading to conflicting decisions and goals (Biresselioglu et al., 2020) or even lacking the competence to develop a specific task (Hult, 2018). Furthermore, subjective and world views of energy experts influence their perceptions on the decisions. Therefore, subjectiveness is in place when making decisions on objective systems (see more on part 1 of the results section).

In addition to these complexities, individuals decisions are influenced by the perceptions of what energy is, this implies that energy cultures are also shaped by the meanings imbued in the concept of energy (Oostveen, 2020; Shove & Walker, 2014). The following section goes through notions of energy that underly energy experts´ decisions.

1.3.2. NOTIONS OF ENERGY SHAPING ENERGY CULTURES

The energy experts' actions are also driven by normative, epistemological and ontological assumptions about the energy.

Voices such as Pope Franci´s calling for the healthier nations to bear the greatest responsibility for the climate crisis can often guide energy leaders and experts (Brulle & Antonio, 2015). Although this can provoke some conscious actions, others' vested interests, as well as inertia associated with behavioral patterns, must be overcome to develop new institutional models capable of effectively dealing with the climate crisis (IPCC, 2015). Decisions about energy systems are strongly linked to philosophical traditions that have developed in specific cultural contexts. These can act as catalysts for promoting sustainability or as barriers to deep environmental thinking. A Western conceptualization of energy, for example, is the current most widely held view about energy in society. Such philosophy is based on the Greek-monotheistic-scientific view, where the ontology abbreviates energy based on the laws of thermodynamics, which means energy is equal to its capacity to perform work (Oostveen, 2020; Shove & Walker, 2014). Such abbreviation on the conceptualization is problematic because it reduces energy to a utilitarian view that reinforces the idea of natural resources as being for meeting human needs. Therefore, other philosophies and views are explored and cross-culturally compared to deepen the understanding of energy. One of those comparisons was made by Ulrich Libbrecht (1928-2017). According to Daan F. Oostveen (2020), Ulrich compared three worldviews about energy: 1. Chinese-Daoist: focus on ´becoming`; 2. Indian-Buddhist: focus on ´not-being`, where the unknowability of energy is absolute; 3. Greek-monotheistic-scientific: focus on ´being`, where energy properties are to be discovered. While, the Chinese-Daoist and Indian-Buddhist views can expand our understanding of energy-humans relations, the predominant worldviews in schools of knowledge and institutions is the Greek-monotheistic-scientific. Such a viewpoint reduces the reality to one that can only be observed, leaving little room for creating the future of energy systems. It also limits current leaders' and energy experts' accountability for their actions in the energy transition, making it difficult to assign responsibility for the human-made impact of energy projects.

The asymmetry in philosophical perspectives and knowledge from other cultures obfuscates the knowledge of other regions, raising concerns about energy justice (Sovacool et al., 2017). For example, reductionist views of energy can result in issues

such as “intellectual colonisation” or misrepresentation and misrecognition of other cultural meanings of energy (Bombaerts et al., 2019 p. 8). Therefore, adopting other philosophical perspectives is an ally in the quest for equilibrium in the energy-society relationships. In this thesis, I deepened the understanding of energy-society based on deep ecology and philosophy of ecology to revel underlying beliefs associated with climate change (chapter 5). Similarly, Benjamin Sovacool et al. (2017) explored global philosophical perspectives to improve energy-society relations, stating that: “Ubuntu philosophy is linked with neighbourhood efforts to foster energy efficiency and decisions about energy resources within a local society, for example. Taoism and Confucianism can represent a plea for respecting due process in energy policy and decision-making, building on human rights protection when executing energy projects. Hinduism is seeking to minimise the extent and allocation of energy externalities, offering affordable energy access to help fight energy deprivation. Buddhism is said to focus on the respect of future generations with energy system management, minimising harm to the environment and the entire world. Indigenous perspectives, finally, can focus on energy systems elaborated cautiously through long-term experience and sovereign cultural procedures, requesting restoration and avoiding disruptive ecosystem transformations” (Bombaerts et al., 2019 p. 11). The richness of local knowledge that those philosophies provide can guide reflective views and propagate decisions based on energy justice principles.

Philosophical insights can boost the Western understanding of reality, which is based on observation and driven by the Cartesian dualism of the material world as distinct from mental rationality. However, this point of view also limits the understanding of causal relations. As a result, dichotomies emerge between humans/non-humans, culture/nature, structure/agency, subjectivism/objectivism, technical/social, and so on. The problem with imposing dichotomies on our understanding of reality is that they maintain the view that humans have a privileged position over the natural world and other species.

Such assumptions shape energy-related social practices. These factors help to shape the narratives and social discourse, mostly those related to the nature of the world and environmental matters, as well as people's perspectives on global problems (ISSC &

UNESCO, 2013). For example, when energy is viewed solely as a resource base, as in the Western conceptualization of energy now interiorized in energy systems, experts are primarily concerned with political, economic, and technological issues (Shove & Walker, 2014). This in turn means frequently accepting the scenario of an energy demand increase and disregarding possibilities of staying in a loop of solutions/problems. For example, factors like increasing population and the effects of climate change of more frequent heat waves increase energy demand for cooling through cooling systems, consequently generating more emissions. However, simple actions such as viewing energy as part of the social practices that reproduce the "bundles and complexes of social practices" can reveal how and why people use energy (Shove & Walker, 2014 p. 41). Thus, deconstructing assumptions about energy, such as the normalization of rising energy demand. Such a paradigm shift can assist in addressing related societal problems rather than accepting them as a rooted system, such as energy poverty, inequalities, and environmental degradation.

Academic research can help to shift paradigms and perspectives on energy. Thus, changes will spread because academic traditions of research and education inform the institutions when designing strategies for the energy systems. However, these academic institutions are rooted in a culture in which Cartesian perspectives and dichotomies are embedded in research practices. Cartesian perspectives reinforce the notion of material and social segregation and the separability between humans and non-humans matters (Hawkins et al., 2017). Tim Ingold (1997) pointed out that "the student of technology is led to believe that a body of context-free, propositional knowledge about tools, their interrelations and how to use them, lies fully-formed inside people's heads, simply waiting to be revealed and written down" (p. 132). As an engineer, I can familiarize. Advances in research structures in energy research are explored in chapter 4.

Energy resources are a source of power concentration. Deep views on cultural values linked to energy practices can prompt introspection about hidden causes of energy-related societal problems. Power concentration around energy sources can also be linked to cultural characteristics (Pierre Bourdieu, 1983). Bourdieu perceives culture, such as information, skills, knowledge, and education, as a form of social capital

(Mendoza et al., 2012). Used as a form of power, individuals and institutions intercalate to distribute resources. For instance the distribution of resources for energy research are a conventional source of hierarchy on sciences matters of technical concerns are seen as prioritary over other areas of inquiry (Haraway et al., 2016; Mendoza et al., 2012). Other forms of social capital proposed by Pierre Bourdieu are economical, social, cultural, and symbolic (Mendoza et al., 2012). Values, power, and culture are reproduced and reinforced by and for individuals as a way of maintaining capital. Bourdieu was concerned with the societal use of resources (capital) as a form of distributing power between actors and institutions, influencing the creation and perpetuation of social inequalities (Mendoza et al., 2012). Studying the existents and emerging energy cultures, mainly nowadays that deep transitions are discussed with normative statements, can be a critical step towards adopting reflexive views of what is needed to deal with the climate crisis. Reflexity theory, of Pierre Bourdieu & Loic Wacquant (1992), by energy experts is critical to avoid the reproduction of actions that will to transitions that reproduce the contemporary preoccupations (e.g. deep infrastructural transition where capital remains as a form of power and control) (Vleuten, 2019). The concept of capital in this thesis is seen as an underlying structure which drives motivations supporting the decisions of energy experts on projects on the energy transition (more on social capital in section 2.7).

The following section explains why new views and theoretical narratives are necessary for the energy sector and climate change problems.

1.4. WHY DO WE NEED TO COME UP WITH NEW THEORETICAL NARRATIVES AND METHODS?

The above section showed how social practices and underlying notions of energy contribute to the energy cultures in societies. I discussed how the energy cultures have embedded practices and narratives that are outdated for the transformation of energy systems. In this section, I present the relevance of narratives and why new narratives are needed to guide the energy experts´ decisions concerning socio-material practices and socio-technical systems.

Narratives are part of the “fabric of the social world” according to social sciences (Lawler, 2002 p. 242). Investigating narratives can shed light on their role in the

emergence of societal structures and the pathways society is taking. In the words of feminist scholar Lynne Segal. “Our own most cherished conceits, stubborn evasions or persistent illusions are all fashioned by a growing stock of cultural narratives, as we try to make sense of the past and its connections to our lives in the present. This […] is what we need to study, not seek to evade” (Segal, 2015 p. 118). Narratives carry the transformations and changes that occurred over time, thus, they are an opportunity to connect the past with the present (Maavak, 2019). As if they are a social memory. Furthermore, since narratives are context-wise, they are powerful in revealing cultural characteristics. Cultural context “delimit what can be said, what stories can be told, what will count as meaningful, and what will seem to be nonsensical” (Lawler, 2002 p. 242).

Another perspective is that we are part of the reality we seek to reformulate (Barad, 2007). With this argument, the energy experts' narratives are even more relevant for future-making because of their role in the materialization of energy systems and how they function as embedded in societies. To Karen Barad (2007), we are not observers of the world, discursive practices in this context do not refer to the description of specific characteristics of systems or phenomena; instead, they reveal humans' intra-activities that consider us as part of the nature and scientific activities as natural processes (Barad, 2007).

Understanding and proposing new narratives for global environmental problems is a major concern of the International Social Science Council (ISSC) and the United Nations Educations, Scientific, and Cultural Organization (UNESCO) (ISSC & UNESCO, 2013). Their report centres on the need for narratives that transcend current social practices in relation to the environment and the underlying complexities and philosophies influencing those practices (like those presented in section 1.3 of this thesis). They identified the following as transformative cornerstones where understanding narratives from the perspective of social sciences and research can contribute: 1. Visions for change, including the need to account for marginalized perspectives and different narratives if alternative futures are to be created. 2. Interpretations and subjective sense-making, where accountability of the underpinning peoples' experiences on climate change is necessary. Mostly those

related to peoples´ values, beliefs, interests, worldviews, hopes, needs and desires (or lack thereof) for the transformations of global systems. 3. Responsibility, where having visions for change and understanding subjective sense-making can lead to allocating responsibilities towards injustices caused by climate change, particularly focusing on populations already in vulnerable positions. Such discussions must be brought to the forefront of scientific research, policies, and practices (ISSC & UNESCO, 2013).

Narratives are required to guide energy experts working with the decarbonization of energy systems since they have a purposive climate change agency (Goodman & Marshall, 2018). Purposive climate change agency is intrinsic in their work since the need for transformations in energy systems is explicit and internalized into social groups (policies, cultures). This leads energy experts to be both reflective and active in modifying the current modus operandi required in energy systems (Hasberg, 2020; Irwin, 2010). Thus, new narratives, coherent methods and theoretical tools can support experts' decisions and actions when modifying underlying structures while promoting society lifestyles toward a more harmonious future (Biresselioglu et al., 2020). The emphasis in this thesis is primarily on insights that enable new narratives beyond the conventional dichotomies between culture-nature, humans and non-humans, and objective-subjective knowledge (aligned with posthumanism scholars' argumentation in section 2.1).

Unprecedented times require compelling narratives that explain the current situation and chart a course of action (Brulle & Antonio, 2015). Those new narratives must be capable of advancing sustainable energy transitions by replacing the notion that existing social, political and economic systems will be sustained (Burke, 2018). As well as assist in overcoming the socio-technical complexities of reducing emissions (such as those mentioned in section 1.2.2). The breadth of knowledge (ranging from technological innovation and solutions to deep environmental values and pro-environmental attitudes) and expertise required for reshaping underlying beliefs and perceptions of energy-society relations and energy cultures require new narratives supporting energy experts. Theoretical and methodological new narratives supporting the energy transitions are critical because a lack of knowledge and expertise can

jeopardize the transformation required to effectively address the climatic problem (Biresselioglu et al., 2020).

In the next section, I focus on the importance of ethical perspectives being embedded into the constructions of new narratives and energy cultures.

1.5. WHY DO WE NEED TO LOOK AT ETHICAL PERSPECTIVES?

In the previous section, I discussed the relevance of narratives in shaping energy experts' decisions and supporting the transformation of energy systems. The main interest of this section is to reflect on how ethical perspectives (fairness, trust, morals, power) shape the energy transition process. Slowly is shifting the research priorities from societal, political, technical, and economic aspects to evidencing the ethical implications of people's practices and as drivers for sustainable energy systems (Sejer et al., 2022). This is due to the realization that energy issues are, in fact, nested into moral dimensions (Sovacool et al., 2016) and moral obligations (Jenkins et al., 2016). In this way, energy experts are tasked with reflecting on their own decisions. For instance, are those decisions maybe favouring their local context, but increasing global inequalities instead of contributing to solve them? How are the research methodologies and knowledge being produced part climate change problematic? What matters of concern are not being included in the discourses and practices? Whose interests are being marginalized? On the top of those questions, energy experts must design strategies that guarantee energy security[8] and avoid the appearance of an energy crisis (such as the current ongoing in Europe). This is to highlight that the discussions and strategies to deal with the emissions and issues related to the climate crisis also depend on the application of ethics and justice principles. Leveraging principles of environmental integrity can induce energy experts behavior towards a willingness of act fairly, which is in accordance with the Article 6 of the IPCC (Schneider & La Hoz Theuer, 2019).

[8] According to Halkos & Gkampoura, (2021) between 50 to 125 million people in Europe are characterized as being in “fuel poverty” (period studied 2004 to 2019). However, Scandinavian countries have the lowest energy poverty issues compared to 28 other European countries.

Energy as a moral concern requires ethical inquiry and frameworks that guide energy experts' practices. The perspective on “Energy decisions reframed as justice and ethical concerns”, proposed by the STS scholar Benjamin Sovacool et al. (2016) has central arguments on the propagation of energy injustices through energy infrastructures and the practices and routines of energy planners and customers. Thus, energy is a question of justice and ethics as much as it is one of economic, planning, and technical concerns. Energy justice frameworks can be seen from the perspective of three levels: distributional, recognition, and procedural. In practical terms, this entails identifying issues, determining who is affected and devising remediation strategies.

As Raphael Heffron et al. (2015) argues, “energy justice begins with questioning the ways in which benefits and ills are distributed, remediated, and victims are recognized” (p. 169). For example, the effects of fossil fuel pollution are a violation of human rights and are unevenly distributed. Children are more susceptible to developing respiratory problems due to poor air quality because they often spend more time outdoor and breathe 50% more air per unit of body weight than adults (Sovacool et al., 2016). Fundamental to addressing ethical issues that underly energy in society is the need to not view energy, as a system of provisional electricity. Instead, we must open the black boxes [9] that currently frame energy so we can address issues of energy justice that emerged with the increasing concerns of energy and societal relations. Not just about the awareness between the interlinkage of energy systems and energy justice as a way to prevent justice by looking at those (Jenkins et al., 2018). Instead energy decisions over energy system must be considered as energy ethical issues, thus also moral ones (Sovacool et al., 2016).

Jonh Rawls´ (1971) social justice principle fundamentally argues for equal liberty principles and opportunity principles. Exerting justice happens when all people have the same rights. Thus, he defended the idea of wealth redistribution. Theoretical

[9] Term used by cyberneticians as a way of simplifying a complex set of commands or a part of a machine. The strategy is to draw a black box, enclosing the part to be disregarded, and focus on the input and output of the systems (Latour, 2000). Similar approach is adopted in engineering, thermodynamics and many other disciplines.

perspectives like from posthumanist scholars, favour thinking about the distribution of responsibilities for the climate crisis, framing energy issues as a matter of perpetuating energy decisions based on principles of justice. For instance, considering energy resources as a system that can be used for power control, the concentration of social capital, and maintenance of social inequalities. In this scenario, the ethical perspectives of energy experts are determinant in redirecting the way energy systems are embedded in society. Since the energy transitions is an opportunity to democratize and advance towards more just societies, ethical and moral values of energy experts are key.

Ethical judgments are necessary to be discussed to equilibrate taken for granted standpoints about norms. The existence of conflicting perceptions of energy shapes how people interact in their daily lives and at work. Also, ethical judgements vary regarding the role of energy in the societies they envision. Furthermore, government interests and public policies shape people's experiences and ethical judgments about energy (Smith & High, 2017).

Decisions based on fair and trustworthy behavior underly democratic systems. Steve Rayner (2010) argues that trust is an institutional characteristic. Similarly, we can think of energy systems as institutions mediated by materials and devices. Principles of trustworthiness can lead to fairer decisions. This is because trust often leads to transparency over decisions. As a result, all the actors involved with energy use, consumption, production, and distribution make decisions for the common benefit of all. The presence of trust in societies, institutions and individuals, can reduce the complexity of implementing energy transition projects (Rayner, 2010), as well as reduce the risks associated with projects.

Energy systems must be recognized as social systems and not technical ones (Rayner, 2010). The remarkable and sharp observation of Benjamin Sovacool (2013) is worth highlighting “it is a mistake to talk about building infrastructure, improving energy security, developing energy resources, forecasting future energy demands, or conducting research on new technologies without first asking what this energy is for, what values and moral frameworks ought to guide us, and who benefits” (p. 3).

Thus, the approach I adopt in this thesis looks at socio-technical aspects from the perspective of ethical standpoints. In the next section, I present the structure of the thesis.

1.6. THESIS STRUCTURE

This thesis consists of two parts presented in ten chapters in total. Part one explores the emergent narratives of energy experts from the NSR and how they shape sustainable energy systems, whilst part two explores the technological narratives that are embedded in socio-technical energy systems.

1.6.1. WRITING STYLE

I preferred to write in first person whenever possible. This research writing style can better translate cultural exploration while preserving identity of cultures studied. Furthermore, the research developed cannot be separated from my prior experiences, worldviews, and identity. Voice, ways of knowing, and conducting research is a socially constructed process (Mitchell, 2017). The thesis is a combination of my published articles and reports, as well as a dissertation-style book. Publishing peer-reviewed articles allowed me to cooperate and learn in practical interdisciplinary research, while developing specific investigations on socio-technical systems. At the same time, the dissertation style was an excellent choice that challenged my thinking to connect case studies to a holistic frame and perspective about the energy experts in the energy transition. Publishing peer-reviewed open access articles was a requirement of the MCSA program, which financed and allowed this PhD to take place. The choice of developing a dissertation-style book was induced by the research culture I was embedded in. Since my PhD experience was divided between a period immersed in the Department of Learning and Philosophy and the Department of Energy, those departmental cultures shaped my thinking and favoured the exploration of philosophies while seeking connections and approaches to think about contemporary problems. Furthermore, the interdisciplinary training contributed to connecting perspectives on society-energy-behavior matter.

1.6.2. PURPOSE AND TARGET AUDIENCE

The purpose is to grasp relevant mechanisms of propagation of certain structures embedeed in energy systems that are a source of inequalities and social capital concentration. In this thesis, I investigate existing narratives toward effective sustainable energy transition. The investigation carried out would be valuable to assist energy experts in developing innovative solutions to avoid the self-perpetuation of the current societal problems in future energy systems and the energy sector, such as carbon lock-in effects.

The target audiences of this thesis are energy experts and practitioners, researchers, policy-makers and all those who aim to understand the role of expertise in driving society transitions. Those groups are considered co-producers of transitions, since diverse types of expertises, knowledge and actors contribute to sustainable energy systems (Norström et al., 2020). I mapped existent and required narratives needed to achieve decarbonization of energy systems. Primarily those related to experts' subjectiveness and their practices and ethical and moral dimensions. Such knowledge can inform energy experts on their rationalities, researchers on future perspectives, politicians on directions of decisions and others on being vigilant on actions of the present.

1.6.3. OUTLINE

In **chapter 2**, the interdisciplinary theoretical foundation for my research is presented. Situated within the work of posthumanist scholars, I got insights from Karen Barad, Judith Butler, Donna Haraway, Rosi Braidotti, and Jasmine Ulmer. Specifically I focus on sociomaterial and material-discursive practices, performativity, agential realism, diffraction, and ethico-onto-epistemological to explore emergent material-discursive practices under the energy transition. In addition, philosophers like Bruno Latour and Tim Ingold supported exploring the challenges of anthropogenic climate change policies due to global and local, humans and non-humans, nature, and culture dichotomies. In addition, the work of Pierre Bourdieu on social capital aided in understanding energy experts´ practices and habitus. Similarly, insights from STS

contemporary scholars like Soshana Zuboff, Benjamin Sovacool, Daniel Hult and many others in journals like Energy Research and Social Sciences provided the structure to explore the complexities of socio-technical problems.

In **chapter 3**, the mixed methodological approach adopted in this PhD research is presented. The qualitative interpretative methodology consists of ethnographic fieldwork, semi-structured interviews, document analysis and systematic literature review.

Chapters 4 and 5 from part one of the thesis: energy experts´ subjective experiences.

In **chapter 4**, entitled (Inter) Disciplinary Energy Research, presents the case of the energy experts in the ENSYSTRA project. It explores the challenges of disciplinary technical thinking for early-stage researchers (ESRs) who are expected to co-generate interdisciplinary knowledge for the energy transition but came from disciplinary training where we are seldom trained to cross the disciplinary boundaries. Tthe chapter also summarizes the outcomes of appendix A (Deliverable 3.2 Model collaboration) and my research article "Reflection through Diffraction: Interdisciplinary in Energy Science" (Godoy et al., 2022). The article is a proposal of an interdisciplinary framework for energy research. Based on methods of co-creating knowledge and is underpinned on Barad´s concept of diffraction to expand the views on subjectiveness and objectiveness in interdisciplinary knowledge production for the energy transition.

In **chapter 5**, Perceptions of the Environment, I provide a discussion on the agents roles and responsibilities in the energy transition. The chapter reflects on the emerging narratives to deal with climate change and the role of the perceptions of the environment when dealing with the energy transition. Chapter 5 is theoretically inspired by, and connected with, my Book Review of "Down to Earth: Politics in the New Climatic Regime" (Godoy, 2020) and my article "Energy transition innovators´ perceptions of the environment" (in preparation).

Chapter 6 and 7 are part of the second part of this thesis: cultures on socio-technical energy systems.

Chapter 6, considers how the cultural traces exert a power role in the production of technological structures, institutions, businesses and ownership models. The chapter is based on the analysis of socio-technical DH systems. We open up the black boxes of the institutional conditions for the customers, situating those with the concept of trust, a valuable cultural trail in Scandinavia. We compare the cases of Denmark (primarily based on consumer ownership systems) and Sweden (the largest focus is on commercial DH systems) to understand how the context plays an important role in the development of energy transition projects (Gorroño-Albizu & Godoy, 2021). As well as our article on "Experts´ Perceptions of the Role of Trust in District Heating Systems: Unveiling the Case of Sweden and Denmark" (Godoy & Gorroño-Albizu) (in preparation). The chapter is inspired by Daniel Hult's studies on DH, Cristian Büscher and Patrick Stumpf's studies on the role of trust in relation to socio-technical systems, Nicklas Luhmann's understanding of trust, and Jacques Ellul, on citizens' participation in political affairs.

Chapter 7, entitled Post-digitalization of the Energy Sector, argues that the ethical turn in the energy sector happened since the realization about the power being granted to digital technologies. The chapter is based on our review of Shoshana Zuboff´s book: The Age of Surveillance Capitalism: The fight for a Human Future: at the New Frontier of Power (Mannov, Oberborbeck Andersen, et al., 2020). As well as on our article "Transformation of Trust in Society: a Systematic Review of How Access to Big Data Energy Systems Challenges Scandinavian Culture" (Godoy et al., 2021) The interdisciplinary review spans from computer sciences literature to the culture of trust present in Scandinavia to discussing the ethical issues if these practices develop or exist in the energy sector.

Chapter 8, discusses the dissertation findings and returns to the core research questions and themes raised through the manuscript. Those unprecedented times require understanding the narratives for sustainable energy transitions. Also, the chapter present the main conclusions of the thesis, summarizing the implications of the narratives on energy transitions.

CHAPTER 2. THEORETICAL BACKGROUND

The previous chapter presented this thesis´ concern, the complexity of sustainable energy transitions and the relevance of energy experts' energy cultures, narratives, and ethical perspectives to form their perceptions of the environment, products, and processes and hence, decision-making. The overall theoretical frame for critical analysis of experts' narratives and the material-discursive practices on sustainable energy transition projects is based on the work of relevant posthumanist scholars ((Barad (2003); Barad (2007); Braidotti (2019); Haraway (1988); Ulmer (2017)). In turn, the ideas philosopher Pierre Bourdieu on habitus provided the basis for my exploration of energy experts' practices. Figure 3 offers a high-level overview of the theoretical pillars of this thesis. Assembling a theoretical framework was necessary due to the interdisciplinary nature of my research. The framework required to be able to capturate the energy experts culture in the NSR, as well as the narratives and ethical perspectives needed to improve socio-technical energy systems and sustainable energy transition projects (Chapter 4-Chapter 7).

Figure 3. Taxonomy of theoretical fields that underpin the research on this thesis. Green: thesis goal, blue: areas of study, violet: research settings [10].

To unravel the practices of energy experts, I followed the sequential logic below:

1. Understand ongoing material-discursive practices and narratives within the frame of the energy transition.
2. Explore the ideology, culture, behavior and knowledge production underlying the practices of energy experts with respect to the transformation of energy systems.
3. Extract insights on the energy transition about ethico-onto-epistem-ological features, practices of knowing, process of being, and of becoming.
4. Understand the role that perceptions of the environment, products, and processes play in forming energy transition cultures.
5. Generate insights about the narratives needed to overcome the dichotomies that drive energy experts' actions. Such dichotomies are between culture and nature, humans and non-humans, and objective and subjective knowledge.

In the next section, I explain the theoretical insights and concepts from posthumanism used to follow the steps above, resulting in the critical enquire on the climate change problematic.

2.1. ANTHROPOGENIC CLIMATE CHANGE THROUGH POSTHUMANISM PERSPECTIVES

The term Anthropocene is used to mark the era in which humans significantly impacted Earth´s geology (Zalasiewicz et al., 2017) and calls for a resignification of our understanding of "human-induced environmental disaster" (Haraway et al., 2016 p. 536). Although it has been contested and pointed out as problematic because it gives the impression that climate change is an exclusive consequence of human action, disregarding possible geological factors, the Anthropocene terminology remains worthy of use. It facilitates the contestation of the global power hierarchy of science (Haraway et al., 2016) and allows us to reflect on our relations with other species,

[10] "Institutions unwritten norms and rules", can be considered the same of the "sense of the game" or "disposition", which refers to an intuitive understanding of social order, following the nomenclature used by Pierre Bourdieu.

helping us to recognize that we live in a multispecies world cohabited by humans and non-humans. Thus, offering a narrative to avoid human exceptionalism, in which the environment is just a background that sustains humans' needs (Fox & Alldred, 2020).

The way in which current societies prioritize human needs over those of other species, and ignore differences between humans, speaks to the assumed meaning of "humanity" (Fox & Alldred, 2019). The term humanity is often associated with being white, male or wealthy, mostly inherited from Western civilizations (Fox & Alldred, 2019; Hickey-Moody et al., 2021). Such understanding is also associated with descriptions of classical Humanities disciplines, where the human is to be assumed as the "basic unit of reference for the knowing subject", and its image is often associated with a Man, considered as a rational animal endowed with language (Rosi Braidotti, 2013 p. 1). Thus, "posthumans seek to decenter the role of humans" since discriminatory views have been pointed as the causes of the climate crisis, social inequalities, marginalization, injustice, and inequality in more extensive contexts (Beck, 2008; Ulmer, 2017 p. 836).

Posthumanism is an umbrella term for a variety of definitions and contextual applications. Among the different posthumanism views, I am building on the perspectives from scholars aligned with planetary-scale problems that reproduce inequalities and injustice of the Anthropocene. As argued by scholars Rosi Braidotti and Donna Haraway, injustices are material, ecological and geopolitical, a more-than-human endeavour (Ulmer, 2017). Thus, moving away from anthropocentrism with posthumanist perspectives means raising the awareness of the global impact caused by prioritizing humans' needs over those of other species, acknowledging alternative modes of thinking. Furthermore, a first step to studying the climate crisis and restructuring societies is recognizing the complete picture of what is shaping our material surroundings (Ulmer, 2017). As pointed out by Anna Hickey-Moody et al. (2021):

> "We use the word posthuman to express criticism of the individual subject, the age of enlightenment, and associated beliefs that predominantly White, male, European men and knowledges are the

> center of our world and knowledge systems. If the White, male, European man can been seen as the model of the human – or as "humanism," then posthumanism is the story of us other human: BIPOC, women, children, the disabled, LGBTQIA+, and our relational becomings with animals, lands, atmospheres, ideas, and things" (p. 214-215).

In this thesis, posthumanism is understood as a methodology that turns the way of thinking about research. By shifting from the focus on humans as the only "possible subject or object of study", it opens to questions of who, how, and what is producing knowledge, thus, including underrepresented elements when situating processes, knowledge and the material context of the practices (Ulmer, 2017 p. 832). This approach, partially because the limited scope of disciplines, leads to a need to reinvent academic fields, their objects of concern, and develop new ethical frameworks adequated for posthuman times (Braidotti, 2013). Posthumanism is a method for studying and perceiving the world. Instead of putting humans on the top of non-human agents, as done in anthropocentrism, posthumanism puts them in the same level (Fox & Alldred, 2019). In this way, posthumanism considers humans as neither privileged nor disadvantaged compared to non-human matters (Fox & Alldred, 2019). It also acknowledges that social and material worlds are entangled in materialization instead of a reality out there to be discovered. Thus, posthumanism offers a breaker of the boundaries established by the classical dualism of nature/culture, humans/nonhumans, subjective/objective by viewing nature-culture, humans-nonhumans, and subjective-objective knowledge as entanglement. Aligned with this thesis, posthumanism offers a way to rethink energy experts' subjectivities and its causal power in the climate crisis, favouring the redefinition of objectiveness to overcome anthropocentrism. Encouraging reflectivity on our role and how we think about ourselves in the Anthropocene.

When talking about the relation between posthumanism and post-anthropocentrism, Rosi Braidotti (2013) argues that "the post-anthropocentric turn, linked to the compounded impacts of globalisation and technology-driven forms of mediation,

strikes the human at his/her heart and shifts the parameters that used to define anthropos" (Braidotti, 2013 p. 5). Due to its trans-disciplinary coverage, posthumanism for post-anthropocentrism adds a level of complexity. While post-anthropocentrism entails the disciplines of STS, environmentalism, and digital culture, posthumanism mobilises the broader disciplines of philosophy, humanities and cultural studies. As Jasmine Ulmer (2017) wrote:

> "[...] posthumanism offers different ways of thinking in and about and without methodology. By reconsidering who and what is social, posthumanism moves away from perhaps the most basic premise within social sciences research. Posthumanism rejects that humans are the only species capable of producing knowledge and instead creates openings for other forms/things/objects/beings/phenomenon to know." (Ulmer, 2017 p. 834)

Recalling that reimagining social structures, systems of beliefs, roles and cultures of energy are necessary for addressing the climate change problem (Clarke, 2015; Valtonen et al., 2020), it becomes evident at this point that insights from posthumanism, developed by scholars like Rosi Braidotti, Karen Barad and Bruno Latour, allow for a theoretically robust standpoint, to "effectively dismantle and destroy a human-centred world view" (Patra, 2020 p. 1). That is the starting point for an ecological reimagining of energy cultures and the energy experts' practices on socio-technical energy systems. I also mentioned how the nature of the climate change is partially a consequence of how energy experts perceive the role of energy in society. Decarbonizing energy systems requires a rethinking of our perception of energy in the Anthropocene. This is one of the reasons posthumanism had an ascending relevance in my thinking as a researcher. It stimulates and provokes a perspective shift on the ontological, epistemological and methodological structures that society is built upon (Ulmer, 2017).

An example of how epistemologies matter for the climate crisis can be drawn by analysing the IPCC reports, which are predominantly informed by modelling tools based on knowledge from natural sciences, insufficiently explore cultural and social

aspects of the Anthropocene (Valtonen et al., 2020). Consequently, the envisioned solutions for the climate crisis are mainly based on technical knowledge and modelling tools, lacking accounts of externalities such as the behaviour routines and habits associated with consumption patterns (Sovacool, 2014). Furthermore, it shows an underrepresentation of questions of energy justice, inequalities, and gender right there at the centre of knowledge production. Matters that could be at the center of enquires in a near future if adequated methodologies, tools, and disciplinary backgrounds adjust to the needs of the current challenges. Therefore, an expansion in group representation, topics and methods is needed, as shown by an analysis of 15 years of research in energy and social sciences (Sovacool, 2014). Such an expansion will increase the range of knowledge and philosophical perspectives for dealing with the climate crisis.

Francesca Ferrando (2016) argued that the "Anthropocene and the actual collapse are only the symptoms" (p. 156) caused by the prevalent human-centred world-view. For her, the solution "lays in philosophy, and specifically, in a theoretical and pragmatical post-anthropocentric shift in the current perception of the human" (Ferrando, 2016 p. 159). Post-anthropocentrism and post-humanistic tools are suited to explore the energy experts' narratives and perceptions about humans' relation to society, the environment, and the solutions proposed for decarbonizing the energy sector in the North Sea Region (NSR). In Chapter 4-Chapter 7, I unpack the narratives of the NSR energy experts when engaging with the environment and the realities of communities in which the energy system projects are immersed. Then, I will present how some energy experts perceive the climate crisis and how such perceptions connect with their actions to shape the NSR energy systems. The posthumanism methods I use to think about the theories, methodologies, and ethical grounds of NSR energy cultures come from scholars like Karen Barad, Donna Haraway, and Jasmine Ulmer, because their theoretical frameworks fit contemporary problems. They help us redesign how we cope with the issues related to the climate crisis by inviting us to rethink the way we act in the world.

The thesis goes from analysing material-discursive practices to doing a diffractive reading of the energy experts' practices, while acknowledging the performativity on the practices under the frame of the energy transition and the ontological-ethical-epistemological framework of the agential realism theory. The key posthumanist concepts that I bring into the thesis and which are the most useful for understanding the practices of energy experts in the energy transition are:

1. Sociomaterial and **material-discursive practices** in socio-technical energy systems: to map the contemporary discussions (concerning, e.g. energy, society, science, and engineering) as entanglement of social and material domains.
2. **Performativity** on the analysis of narratives: understanding of responsibility.
3. Agential realism and the ethico-onto-epistemological framework, as a way of understanding the inseparability of matters of ethics, being and knowing.
4. The concept of **diffraction** particularly changed the way of perceiving interdisciplinarity and boundaries of socio-technical disciplines.

In the next sections, I present those concepts in detail within the context of the energy transition.

2.2. SOCIOMATERIAL AND MATERIAL-DISCURSIVE PRACTICES IN SOCIO-TECHNICAL ENERGY SYSTEMS

Material-discursive practices are about “seeing the discursive effects of the material, and the material effects of discursive” (Orlikowski & Scott, 2015 p. 698). Considering matter and discourse a single entangled entity results in new phenomena more than a purely additive account of discourses and materials. According to a Baradian account, material-discursive practices are concerned with the entanglements of matter and meaning (Barad, 2007). This implies that the materials (e.g. technologies, apparatuses, tools, and the physical world), with which energy experts interact, influences their discourses and practices, and vice versa.

The relevance of material-discursive practices as an entangled process is a foci on Karen Barad´s theory of agential realism. Agential realism considers the materialities

and the social not as separated or pre-existent entities (using the portmanteau "sociomaterial" (Leonardi, 2013)). Instead, they emerge as a consequence of entangled practices, influencing the materialization of structures[11] in society (Hawkins et al., 2017). Barad´s analysis were built upon the philosophical implications of quantum theory, where she brought into attention issues of objectivity, measurement, and ethics on the underlying practices of science. Adopting such a set of theories proposed by posthumans scholars for the energy sector can provide new ways of thinking when accounting for the factors (e.g. more-than-humans) contributing to the materialization of socio-technical systems. The relevance of Barad´s insights about the materialization of matters relies on offering a more inclusive account of reality, helping to deal with questions of fairness, power imbalances, and justice this is precisely the concern of many STS scholars on the current transformations in the energy sector (see aspects of energy justice explored in Bombaerts et al., 2019; McCauley et al., 2019).

Applying the posthuman theoretical toolbox for understanding socio-technical systems reveals the intertwining of material-discursive practices. For instance, socio-technical systems are shaped equally by technological feasibility factors and people´ interests for specific settings. Thomas Skjølsvold (2014) identified that the material-discursive practices in the development of smart meters happened in two modes: translative and transformative. The translative is driven by specific actors´ interests who push for a particular technology. In comparison, transformative works subtly with symbolic and cognitive meanings and aligns the technologies' becoming with the imaginary collectives. His study, covering the period from 1998 to 2008 in Norway, shows that the development of the smart meter unfolded through iterative intra-actions of spokesperson, technologies, market forces, and policy implementations, among others (Skjølsvold, 2014). On it, people´s expectations, imaginations about the future, and actors' involvement play a central role in the development of regulations and on the development and implementation of the technology. However, ethical

[11] "Structures are specific material configurations/(re)configurings of the world" (Barad, 2007 p. 237)

considerations when people are pushing for one technology or another were not brought into the discussion.

Posthumanism tools can be an ally for considering people's values, morals, and ethical premises that drive the materialization of energy systems when adopting strategies for mitigating and adapting to climate change events. An example where aspects of ethics, imaginations and values are explored, in the context of STS, is the book with a focus on transhuman views of technology, edited by Hava Tirosh-Samuelson and Benjamin Hurlbut (2016). On it, contemporary imaginations of technologies are understood as having a central role in the development of technological innovations and as a force for social and historical transformations. For instance, Franc Mali (2016) looks at the impact of cognitive factors, such as expectations, hopes, and fears on the progress of science and technology. Another area of concern of STS scholars is regarding people's imaginations and their relations to the future of technologies. For example, the work of Sheila Jasanoff (2015), she introduced one definition for socio-technical imaginaries based on the existence of a positive collective imaginary; a "desirable future" that influences the making of the present (p. 28). We could think that energy systems are shaped and shape our values and norms as well as those systems are influenced by how we wish those systems to be (based on the insights of David Hulme about "what is" and "how we ought to be[12]"). But, Sheila Jasanoff´s (2015) concept of socio-technical imaginaries embraces humans' subjectiveness (similarly to posthuman scholars) in the making of science and technologies. This is because they are performed visions of futures, that emerge from a shared understandings of the social (Jasanoff, 2015).

Her definition of socio-technical imaginaries expands on what is involved in the materialization processes, it attempts to tackle power and morality aspects once they intersect with scientific and technological forces (Jasanoff, 2015). But she is also acknowledging that our values and norms do not unidirectionally shape science and technologies in society, but "our sense of how we ought to organize and govern

[12] David Hulme—what is—ought to be problem. His study explores the positive statement of what "it is" and a normative what "ought to be".

ourselves profoundly influences what we make of nature, society, and the "real world"" (Jasanoff, 2015 p. 4). Similarly, in this thesis, I pay attention to aspects of perceptions of the environment, products, and processes and discuss those supported by posthumanism in the context of Science, Technology and Society (STS) inquiries. By navigating highly interdisciplinary areas (spanning from human-environment relations to cultural transformations brought by technological apparatuses), the contributions of this thesis align to some discussions on the STS field that still are black boxes. As such, the technologies, compared to pandora boxes, have internal complexities, but they achieve power due to its ubiquitous and obscure characteristics (Latour, 1999). For instance, those related to the energy experts identified by David Hess & Benjamin Sovacool (2020) include: 1. Thinking pathways that, instead of legitimazing the status quo, allow a democratic engagement between experts and citizens; 2. Broadening analyses of the relations between expertise, knowledge, and technology, and 3. The effects that socio-technical systems have on people and things when they are constructed and reimagined (Hess & Sovacool, 2020).

With this in mind, this thesis navigates an interdisciplinary context to understand the energy experts' perceptions and their relations with institutional configurations and the development of socio-technical systems. This contributes to the STS challenge of "bringing social thickness and complexity" into technological development (Jasanoff, 2015 p. 3). It also aligns with energy-society-technologies matters that concerns entire journals, like the Energy Research and Social Sciences. The terminology and language used are worth of clarification because it can be academic jargon for some audiences, preventing a productive reflection (Leonardi, 2012). For this, I follow the interpretation of Paul Leonardi (2012), who clarified the concepts of materialities, socio-material and socio-technical systems, and further, I align those concepts with the field of posthumanism. See Paul Leonardi (2012) description, in his own words:

> "People have intentionality and technological artifacts have materiality. As people approach technological artifacts they form particular goals (human agency) and they use certain of the artifact's materiality to accomplish them (material agency). These collective

> human (social) and material agencies become imbricated in the space of practice. Certain imbrications produce changes in the abstract "social" formulations (e.g. roles, status, etc.) that occupy so much of organization theorists' attention. Alterations in these abstract formulations can shape future patterns of imbrication, which, in turn, can bring changes to an artifact's materiality or a person(s)' intentionality. This mutual shaping of social and technical subsystems [...] is what defines a socio-technical system. We might usefully be reminded that organizations are socio-technical systems" (Leonardi, 2012 p. 24).

Such concepts are in the context of the chapters and articles of this thesis since I consider that energy experts engaging with the energy transitions are dealing with socio-technical matters (Büscher et al., 2018). An important clarification here is on the understanding of an energy transition. I argue that the transformations undergoing on energy systems and the way we use electricity are contextual and culturally dependent, and thus, there is no single and unified definition of an energy transition[13]. The energy transition aimed at decarbonising the energy sector is occurring with different scientific perspectives (e.g. methodologies, disciplinary thinking), techniques and technologies (e.g. tools, systems), and social and human aspects (e.g. culture, beliefs). As explained above, the cases explored in this thesis are based on changes happening in specific socio-technical systems. In addition to an exploration of experts´ subjectiveness (such as their perceptions), I explore other factors that may influence their actions because socio-technical energy systems are largely formed by society and institutions, and not only energy resources and infrastructures (Li et al. 2015). Thus, analysing experts´ practices and narratives in relation to those systems reveal holistic views about socio-technical energy transitions since they involve a "deep entanglement of technologies and innovation with sociocultural, political, and economic elements" (Rohracher, 2018 p. 2).

[13]Reflection upon Collon´s idea that there are multiple ways in which economic activities can be organized (Butler, 2010).

After having set the context of socio-technical systems and how they are understood, I remind the reader that in this thesis, those systems are explored through the understanding of material-discursive practices voiced by energy experts. Concerns are mainly with the entanglement of material-discursive practices of energy experts in the energy sector and with including analysis of more-than-human factors, while also exploring how energy experts perceive nature, environment, and cultures. The rejection of the distinction between humans and non-humans agents is to refute the anthropocentrism point of view on those systems, where, historically, the human-centered development of society leads to the lack of deep connection of what it means to be human (Latour, 1996).

Focusing on energy experts' narratives, actions, and their material engagement allows us to "think of humans concerning a more-than-human world" (Kuby, 2019 p. 4). This is because analysing material-discursive practices produces insights on how things come to matter, considering the engagement of, e.g. subjects and objects, nature, and culture. The entanglement of material-discursive practices consists in thinking about humans and non-humans as single entities that produce realities, knowledge, and relationships (Barad, 2007; Kuby, 2019). For instance, Barad´s work intends to explore the dynamics and processes of materialization of space, time, and bodies through the "incorporation of material-discursive factors (including gender, race, sexuality, religion, nationality, class, and technoscientific and natural factors)" (Barad, 2007 p. 35). In a broader sense, she reflects on the importance of accounting for bodies, humans, non-humans, and social and natural factors into materialization:

> "There is a host of material-discursive forces-including ones that get labeled "social," "cultural," "psychic," "economic," "natural," "physical," "biological, " "geopolitical," and "geological"-that may be important to particular (entangled) processes of materialization." (Barad, 2007 p. 66)

For Karen Barad to be objective, we need to account for the specific materializations we are part of, also meaning that we need to take into account entities where subjectiveness places a central role. Hence, more-than-human factors are entangled

into the material-discursive practices, such as apparatuses, which Barad considers as material-discursive practices rather than laboratory setups that "embody human concepts and take measurements" (Barad, 2007 p. 146). Understanding the apparatuses means looking at what guarantee the functionality of the infrastructure provides, what is excluded and included, as well as the underlying assumptions in the materialization of socio-technical energy systems. Apparatuses produce differences because of "boundary-making practices that are formative of matter and meaning, productive of, and part of, the phenomena produced" as well as "material configurations/dynamic reconfiguring of the world" (Barad, 2007 p. 146). Thus, the concept apparatus describe the dynamic configurations reflected in the material-discursive practices, which form the possibilities and impossibilities of materialization of energy systems.

Clarifications on the practices of materialization of the energy transition, emphasizing the context of humans, are relevant because the challenge of problems in the twenty-first century entail coexisting areas of, for example, the anthropocene and the development of artificial intelligence. Consequently, controversies on the discourses can emerge, such as those discussed in chapter 7 about the digitalization of the energy sector. While scientific evidence supports the voices to mobilize smart grids innovations and demand response, indicating that smart devices can contribute to solving the intermittency problem of RES (Geels et al., 2017), discurses from others scholars question the efficacy of such technologies and the research issues of focusing on innovating to this direction, e.g. rebound effects, the threats to people´s health, and the underlying motivations of being driven by economic reasons (Chin et al., 2019; Zuboff, 2015). Thus, depending on which apparatuses, material-discursive practices, perspective, and theory are in place, the sense-making in relation to the events differ. Phenomenologists could argue that it all comes down to a question of perception, system theorists to a question of observation and hermeneuticians to a question of interpretation (Schmidt, 2019).

The theoretical goal of this thesis is thus, not to provide a characterization of all the material-discursive practices undergoing the energy transition, but to reflect on the existing problems or challenges of some current material-discursive practices for

decarbonizing the energy sector. At the same time, the aim is to make sense of energy experts' actions that could potentially provoke integrative directions towards transformations of socio-technical energy systems. The analysis here, of “discursive and non-discursive” practices, contributes to dismantling the idea that societies and systems like those under the frame of the energy transition are an “existing and autonomous reality” (Butler, 2010 p. 148). The underlying assumption is that an energy transition is a performative act, and this will be explained in the next section.

2.3. PERFORMATIVITY ON THE ANALYSIS OF NARRATIVES: UNDERSTANDING OF RESPONSIBILITY

Performativity is concerned with the power of language in the production of material bodies. This is precisely the proposal of a performativity understanding of posthumans scholars like Karen Barad (2003): to question the power that language represents to define things. She argues that a “performativity understanding of discursive practices challenges the representationalist belief in the power of words to represent preexisting things” (Barad, 2003). The use of representations as a way of understanding the world´s reality is a shared practice of scientific realism and social constructivists, which has at Cartesian Dualism its core. Cartesian is a term associated with René Descartes's understanding of reality as existing a separability between reason and emotion, of mind, and the material body, where the mind and soul are considered as nonmaterial (Mahy & Wallace, 2022). Barad, working with the notions of performativity, material-discursive practices, materialization, agency and causality, inquires about the correspondence between descriptions and reality, contesting the belief that words and things represent reality (Barad, 2003). The consequence of a Cartesian division, according to the reflections of Ian Hackings and Joseph Rouse, is that it introduces a dichotomy between internal and external realities (Barad, 2007). For example, in relation to the belief that the practices of science can represent nature or culture, Barad inquired, “does scientific knowledge accurately represent an independently existing reality?” (Barad, 2003). Such characteristic of representation can be peeled off in the works of scientific realists and social constructivists, as well as in the practices of science and technology in society (immersed in the Western

culture) that perform under the belief that there is an objective representation of reality:

> "both scientific realists and social constructivists believe that scientific knowledge (in its multiple representational forms such as theoretical concepts, graphs, particle tracks, photographic images) mediates our access to the material world; where they differ is on the question of referent, whether scientific knowledge represents things in the world as they really are (i.e., "Nature") or "objects" that are the product of social activities (i.e., "Culture"), but both groups subscribe to representationalism" (Barad, 2007 p. 48).

The perspective of performativity allows for the questioning of the ontologically and epistemological separability of entities, inviting us to rethink what is being represented. For example, in relation to the practices of science when understanding the world: "Practices of knowing and being are not isolatable, but rather they are mutually implicated. We do not obtain knowledge by standing outside of the world; we know because "we" are of the world" (Barad, 2003 p. 829). Adopting a performativity understanding of the scientific practices requires a direct material engagement with the world since knowing does not come from standing at a distance and representing (Barad, 2007 p. 49). Representationalism itself "(like "nature itself," not merely our representations of it!) has a history" (Barad, 2003 p. 806). As Ian Hacking (1983) wrote: "People represent. That is part of what it is to be a person" (p. 144). With this in mind, a shift from seeking accurate representations of reality to being accountable for the actions that influence societal structures of societies, it is a call to take responsibility for our practices (Barad, 2007).

In his PhD thesis, Johannes Kester (2016b), investigated the politics of energy security using the concept of performativity (getting insights from Butler, Barad and Foucault). He makes a theoretical distinction between performativity in Butler´s definition from Barads´ (and Latour) work. While performativity, for Butler, "highlights what discourse does to non-discursive". She "remains focused on discurse and the materialization it initiates". In comparison, Barad and Latour offer a broader understanding, "push the argument by officially moving away from a preference of

discourse to the relations that shape objects. These relations include the relation between humans, between minds and bodies (discourse-non-discursive), but also the interactions or cause-effect relationships between material "nodes" (who themselves exist out of relations)" (Kester, 2016b p. 204).

In this way, since performativity allows to see the relational effects of humans and non-humans matters, their interactions and cause-effects relationships, it is possible to have holistic perspectives about the practices in the energy transition. We can consider that insights from scientific, social, and political, not as separate entities but as a single domain, favoring accountability of how and what is being materialized in the energy transition. This allows us to be more accountable for the future of the energy systems. And allocating responsibility for what is being done or not taken action upon. Energy experts with holistic perspectives and interdisciplinary mindsets are more likely to be able to reflect about the directions of the energy transition.

In recent years, interdisciplinary insights about climate change and energy systems related fields were gained by applying performativity theories. For example, as a way to understand the narratives underlying emergent green economies (Bracking, 2015; Sullivan, 2014), as a way of translating national goals to local community sustainable energy transition projects (Scotti & Minervini, 2017), on evaluating policy instruments as a form of governance in transition management (Voß, 2014), as well as analysing the performances of different players (knowledge institutions, government, local population) about gas extraction for guaranteeing energy security (Kester, 2017). Such studies make it possible to see that the energy transition is a performative act in itself. Performed differently by many humans and nonhumans components.

Performativity perspectives allow us to see the intra-actions between all the parts of a system (e.g. when the disciplinary habitus are in place we are susceptible to losing the holistic account of what is contributing to the materialization). Looking at the energy transition with an interdisciplinary perspective (not as just the sum of separate factors and entities, e.g. disciplines, actors behaviour, technical features) allows us to see the intra-actions through. Thus, the material-discursive practices can provide a more accurate notion of what is emerging (Barad, 2003). As Thomas Skjølsvold (2014)

argues, the performativity of socio-technical systems implies that “whenever a future is evoked, discussed or imagined, it shapes our present” (p. 27).

Performativity theory can then contribute to understanding how energy systems and the transformations in the systems are happening and materialized, as well as to help make send of energy experts' perceptions of their role in shaping those systems. Performativity theory unpacks how expert perceptions are influenced by their cultural values in which they are immersed and how perceptions are translated into actions for energy structures.

In this thesis, I want to identify performances of culture and those matters which deserve attention for being or not aligned with the narratives for sustainable transition required for tackling the climate crisis. I do so by identifying performativity characteristics in the practices of energy experts based on Barad´s understanding that matter (e.g. socio-technical systems) is also performative. However, I do not intend to make a performativity reading of practices of the energy experts. Instead, I examine experts' perceptions regarding their role in the future of energy systems. Thus, performativity is identified in the material-discursive practices of energy experts. This is seen in the practices of disciplinary knowledge production (e.g. interdisciplinary energy research explored in chapter 5, as well as in the culture of surveillance capitalism and digitalization of the energy sector in (chapter 8), and the socio-technical characteristics shaping the practices of energy experts explored in chapter 6.

The mapping of practices/doings/actions in sustainable energy projects with the performativity understanding allows insights into ethico-onto-epistemological matters and discussions on these matters as inseparable entities. Next I explain the relevance of the ethico-onto-epistemological framework nestled in the agential realism theory of Karen Barad.

2.4. AGENTIAL REALISM: ETHICO-ONTO-EPISTEMOLOGICAL

In the above section, I reviewed how a performativity understanding of energy systems shows how the materialization of such systems includes the objective and subjective actions of humans and non-humans agents, “the object and the subjects do

not preexist as such but emerge through intra-actions" in the production of material bodies (Barad, 2007 p. 39). It also means accounting for that natural elements (like the dynamics of nature) and social elements contributing to systems´ futures (Murphy, 2004). Intra-actions, signify that there is a "mutual constitution of objects and agencies of observation within phenomena" (Barad, 2007 p. 197), where there is an inseparability between the practices of doing, being and knowing, of ontologies and epistemologies. The notion of an inseparability of ethico-onto-epistemological matters was introduced by the agential realism theory of Karen Barad. The emphasis of her theory is on anlysing scientific knowledge, technoscientific practices, and other practices in the world and pointing out that on these, matters of ethics, ontology, and epistemology are entities that do not pre-exist before interacting, so they intra-actively co-constitute the world (Barad, 2007).

The essence of the agential realism of Karen Barad (2007) is that the ontology of the world not by interaction but by intra-action. Interactions assume that the entities exist in priory, whereas in intra-action they are mutually constituted.

Questions of ethics and responsibility are of immense relevance to Barad. Similarly to Barad´s dedication to ethical matters on science practices is the work of Rosi Braidotti (Braidotti, 2013). These intra-actions between a set of elements drive sustainable energy projects and therefore, our different practices are the materialization of the world (Barad, 2007). Thus, understanding what is contributing to the future of energy systems in this thesis means looking at socio-technical matters. On those systems, ethico-onto-epistemological theoretical framework helps tracing the materialization of the energy transition that is emerging in the practices of production of scientific knowledge and scientific facts.

2.5. DIFFRACTION INSTEAD OF REFLECTION

The diffraction methodology of Barad, borrowed from the physical phenomena proposed by Bohr, is useful for understanding the effects of material-discursive practices in the energy transition. Diffractively reading entails thinking about the "social" and the "scientific" together, allowing to incorporate e.g. feminist and queer theory, as well as scientific studies. Those fields do not imply an absolute exteriority

relationship, although they appear to be distinct separate entities and driven by diverse sets of concerns (Barad, 2003).

Barad, in a diffractive reading of Foucault and Butler, argues that is lacking an adequate definition of the relationship between the material and the discursive practies. (Barad, 2007 p. 146). Thus, Karen Barad rejects the metaphor of reflection in favour of diffraction. Diffractive reading as a research methodology allows focusing on the performative power of the knowledge-making practices and the ethical and political implications of such practices (Barla, 2021). To Barad, “Different intra-actions produce different phenomena” (Barad, 2007). An example is choices of methodology, e.g. inductive and deductive approaches, which lead to different research results. While the reflective approach focuses on finding an “accurate” representation of reality, diffraction allows us to read insights into one another, emphasising the patterns of difference rather than limiting by the ideas of representation.

An example of this is how the diffraction perspective and representations, are analysed, accounting for what is making a difference in the world. This means that the practices matter and the world is materialized differently through different practices (Barad, 2007 p. 55).

To be entangled is to lack independent existence, this means that to analyse the energy transition as the sum of the parts fails to consider the mutual influences of humans and non-humans agents. This lead to acknowledging the dynamics of nature and its influence on the future as much as the one that society has (Murphy, 2004). Thus, matters of fact have been replaced with matters of signification, aligned with the importance of language, discourse, and cultures.

Having established the groundwork of posthumanism theories for the climate crisis, I will discuss the impact of energy experts' behaviour, practices, and habitus on driving sustainable energy transition projects in the following section.

2.6. INFLUENCE OF ENERGY EXPERTS AND THEIR HABITUES

As stated in the introduction of this dissertation, the impetus and impediment for action on the specific challenges energy experts confront are influenced by energy

cultures, narratives, and ethical frameworks (sections 1.3 to 1.5). Before delving into the habitus of energy experts in the energy sector, it is reasonable to ask what constitutes an energy expert in society. The definition of experts introduced in the problem statement of this thesis (section 1.1) argues that an expert is someone who has recognized expertise in a specific domain (Haas, 1992). Energy experts interviewed in transition literature are generally citizen activists, environmental NGOs, politicians, and academics (see, for example, Kainiemi et al., 2020). From the standpoint of political power, experts are recognized as having an authoritative word in policy-relevant knowledge (Ellul, 2015). But, Jacques Ellul (2015) himself clarified that experts´ power is limited to the "start of a process", because systems can change due to technical limitations encountered by technicians, who are responsible for providing technical feedback or driving technical changes. Although it is not the purpose of this thesis to assess the political power of energy experts, I assumed that such influential power exists (for example, by proposing new regulations (chapter 7) and producing policy briefs, scientific reports, and knowledge (chapter 4)). In practice, energy experts provides solutions to current energy systems challenges (Ballo, 2015). In this thesis, the energy expert´s context is energy transitions, where they are in a position to enable action and inaction, and are shaping society through technological apparatuses and structures (Parag & Janda, 2010; Zohar et al., 2021), as well as building science "facts" (Latour, 2005).

The social power of energy experts is in the materialization of energy systems´ projects in the energy transitions. I consider the energy experts as agentive participants in the energy transitions, where their practices are influenced by the mutual constitution of materialities and discourses (Barad, 2007). Furthermore, they are entrusted (directly and/or indirectly, conscious and/or unconsciously) with decisions regarding restructuring the NSR´s energy systems. Their roles and responsibilities are dealing with the complexities of the energy systems; a matter of concern to current and future societies. These are challenges that go beyond having a good plan to get society there (to a sustainable world). Rather, it is about rethinking the underlying structure of society and walking on an uncertain pathway. Uncertainty exists in part because the methods and theories for rethinking social structures have a historical

memory which materializes (through) time (Barad, 2007 p. 203). As a result, the practices of energy experts may perpetuate the same current societal problems. The concept of habitus can be powerful in revealing their practices, because individual habitues reflect the groups that, according to Pierre Bourdieu (1994), can be "subjective but non-individual systems of internalized structures, common schemes of perception, conception and action" (p. 60). The habitus in energy practices are explored in this PhD research project through the entanglement of materials-discourses in specific socio-technical configurations[14]. This exploration reveals practices to enhance the reflective habilities of energy experts about the materialization of the socio-technical energy transition and their respective roles in the becoming[15]. As Timothy Wells (2021) argue, in postqualitative fields, becoming is an indeterminant and incalculable process, thus it is not about mapping the transformation process instead about "opening up and extending life" (p. 173).

Pierre Bourdieu´s (1990) work on habitus offers theoretical grounds for understanding energy experts' practices and their role in shaping socio-technical systems. This favours the investigation of unexplored matters in three decades of climate research, such as those observed by Isak Stoddard et al. (2021): what are the expert's subjective views that shape energy systems? How do their agency shape the social context? How do the experts' backgrounds, life histories, and imagined futures shape energy research, knowledge production, apparatuses envisioned, and the shaping of systems? These questions are related to the research questions of this thesis. For example, I investigated expert values of experts through their perceptions, observed how cultural characteristics influence practices, and observed methods and narratives supporting transition, as well as their ethical perspectives on energy transition projects.

The complexity of the climate crisis and the energy transition is hidden with tensions between structure and agency. The study of habitus proposed by Bourdieu aims to transcend the dichotomies between structure-agency, subjectivism-objectivism-theory, and practice. Bourdieu looked at the relationship between agency and structure

[14] See for example district heating systems (chapter 7) and digitalization (chapter 8).

[15] Matter is intra-actively co-constituted (Barad, 2007).

to gain knowledge about social complexity (Costa & Murphy, 2015). Understanding the ‘self’ in this thesis, corresponding to the energy experts, can be approached via analysing people's internalized behavior, perceptions, and beliefs. Internalized behaviors, perceptions, and beliefs are what Bourdieu collectively refers to as ‘habitus’. The study selected groups of energy experts' of NSR driving the energy transition through socio-technical energy systems to give a perspective on the collective practices and the underlying energy culture. Energy experts conform to communities, which are characterized by sharing a set of 1. Normative and value-based beliefs; 2. Causal beliefs (derived from actions and desired outcomes); 3. Notions of validity based on their intersubjective knowledge; and 4. Shared practices (Haas, 1992). Those energy communities or energy cultures hold specific values, and understanding those when radical and incremental changes are to be proposed is of extreme relevance and urgency.

Bourdieu's understanding of ´habitus`, as both a methodological and theoretical tool, aimed at reconciling the theory with practice. It serves as a foundation for understanding how energy experts construct and re-construct the social worlds in which they are embedded. Habitus produces social structures and practices. Thus, since habitus generate practices those reflect the social conditions that produced it, they also are considered to reproduce structures (Power, 1999). Understanding which practices are associated with the reproduction of habitus that maintain the rising greenhouse gas emissions can induce energy experts towards an reflectivity ability of their practices. This is also aligned with the ideas proposed by Sheila Jasanoff (2018), for whom, energy experts should mind and care for adopting approaches that promote technologies of humility by asking for a sensibilization of the problems in the world when unfolding transitions. For example, by emphasizing on improving the lives of people who are affected by global changes, by acknowledging vulnerabilities, and those practices that have shaped policies, class, etc. Favouring the comprehension of policies and innovations on countries, regions and people (mainly those who are already marginalized). Equipping energy experts with reflective tools on their energy habitus helps with their realizations that actions have effects. A concluding remark is that habitus also enables understanding the "complex social process in which

individuals and collective ever-structuring dispositions develop in practice to justify individuals' perspectives, values, actions, and social positions" (Costa & Murphy, 2015 p. 4).

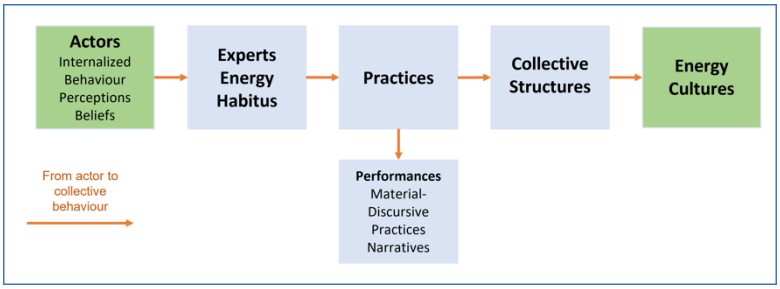

Figure 4. Understanding energy cultures by exploring material-discursive practices and narratives of energy experts.

Figure 4, shows how the actors pathways is influenced by habitus, practices, performances, collective social structures and conform energy cultures. The collective behavior that is reflected in energy cultures, are of great importance for the energy transition since collective actions are effective to destabilizing regimes, such as those controlled by industrial monopolies or political resistance (see the example of Chile by Gloria Baigorrotegui (2019). Having set the grounds of energy experts' practices and habitus, in the next section I dive into social capital and the field to understand the context that can influence the directions of the energy transition.

2.7. HABITUS, FIELD THEORY AND SOCIAL CAPITAL

The most discussed concept from Pierre Bourdieu in this thesis has been habitus, which is also a tool for reconstructing the social structures. Its significance stems from the fact that habitus, and practices, reflect social structures and history that is internally embodied in individuals (Power, 1999). Such internal structures, fostering dispositions for social actions, also influence individuals´ predispositions to social environments. The habitus, as a reflective tool, helps to understand an individual´s dispositions and approaches to social practices (Bourdieu, 2000). Individuals can engage in various dispositions conforming to a social field. Social fields become

systems of permanence, schemes of perception, thoughts, actions, and habitus of individuals.

The main aspects of Bourdieu´s sociology theory was summarized by Raymond Morrow and Brown David (1994) as: "a) society is a system of dispositions understood as social fields, b) habitus as the mediation of subjective and objective, and c) social and cultural reproduction as a process of continuous restructuration that reproduces relations of power" (in Pizanias (1996) p. 652).

Habitus, having an embodiment characteristic, is a central aspect. This is because habitus is not on the level of discursive consciousness. Rather, the internal structures become embodied and deep. "The power of making visible and explicit social divisions that are implicit, is the political power par excellence: it is the power to make groups, to manipulate the objective structure of society" (Pierre Bourdieu in (Pizanias, 1996 p. 659)). Thus, the individuals understanding of how the field and social structures function reflect on how individuals sense the game or understand the unwritten rules on societies (for example those explored in chapter 7). Factors like a lack of transparency of those unwritten rules on societies can be a way of reproducing social forms of domination by societies and individuals. For example, in the disciplinary structure, the faculty habitus of university departments can be a source of prejudices and knowledge capital exclusion if scholars are not familiarized with those specific unwritten rules (see more in Mendoza et al. (2012).

The field is another important concept. In the field is where social agents will have a bodily disposition. Consider it a multidimensional space in which each individual will occupy a position. The embodiment of individuals in the field is critical for understanding social capital. Because a person is defined not only by the social class to which they belong, but also by the types of capital he can articulate through social relations. Partices, habitus, systems of dispositions, and fields are part of the structure that allows accumulated capital or/and social capital. Highlighted are four specific ones: economical, cultural, social, symbolic. Real activities are those in which the "world through which the world imposes its presence, with its urgencies, its things to be done and said, things made to be said" (Bourdieu, 1992 p. 52).

2.8. THEORETICAL OVERVIEW OF THESIS

As this dissertation was supported by research articles, the Table 1 shows the details of the articles and the connection with the theoretical background of the thesis. It includes a detailed overview of the connection between the articles and chapters, the concepts explored and the relation with the narratives in the energy sector.

Table 1. Overview of the thesis in connection with the theoretical background.

Status	Document Type/ Title	Chapter number	Context	Theoretical background	Link to the thesis research questions
Published	Deliverable 3.2 of ENSYSTRA: best practice guidelines for model collaboration.	Four	Education and organizations relationship; Methodological and organizational aspects of collaboration; Challenges of disciplinary, interdisciplinary, multidisciplinary, and transdisciplinary research; Horizon 2020 and MSCA funded projects.	Performativity; Ethico-Onto-epistemological; Diffractive Reading; Habitus.	Experts´ perceptions of the processes; Energy experts´ energy cultures shaping their practices; Energy experts' ethical perspectives.
Published	Interdisciplinary energy research: cogenerating knowledge in a North Sea energy project.	Four	Interdisciplinary Energy Research; Cooperation; Disciplinary technical thinking.	Karen Brad; Posthumanism; Agential Realism; Diffractive Reading; Post-qualitative methods; Habitus.	Theoretical narratives and methods supporting energy transition; Experts´ perceptions of the processes.
Published	Book Review: Down to earth: politics in the new climatic regime.	Five	New narratives for climate crisis; Anthropological futures; Dichotomies between narratives of globalization and localization; Epistemological reflection on the climate emergency.	Bruno Latour; Geopolitics; Climate Change Politics; Humans and Non-humans Actors/Relations; Anthropocene; Habitus.	Theoretical narratives and methods for sustainable energy systems; Experts energy cultures shaping their perceptions of the environment; Reflection on the dichotomies between local/global, nature/culture.
In preparation	How energy transition stakeholders perceive the environment?	Five	Human-environment relationships; Dichotomies between nature and culture, nature and environment; Perceptions of the environment driving the energy transition.	Tim Ingold; Perceptions of the environment; Energy Experts; Performativity; Diffraction Reading.	Role of energy experts´ perceptions of the environment in the transformation of sustainable energy systems; Experts energy cultures shaping their perceptions.
Published	Getting fair institutional conditions for	Six	DH; Denmark; Sweden; Institutional Conditions; Consumers Acceptance.	Material-discursive practices; Performativity.	Values of energy systems for society; Energy experts´ ethical perspectives, e.g. fairness, power, trust.

	district heating consumers: insights from Denmark and Sweden.				
In preparation	Trust in socio-technical systems: the case of district heating.	Six	Role of trust; Reducing complexity; Sweden; Denmark; Active and Passive Participation.	Performativity; Habitus.	Energy experts´ethical perspectives, e.g. trust, morals, power.
Published	Review: The age of surveillance capitalism. The fight for a human Future: at the new frontier of power.	Seven	Surveillance capitalism; Data Culture; Science Technology and Society (STS); Digitalization Energy Sector.	Shoshana Zuboff; Social Capital; Ethico-onto-epistemological; Performativity;	Energy experts´ethical perspectives, e.g. morals. Risks of intentional human practices of digitalizing societies.
Published	Transformations of trust in society: A systematic review of how access to big data in energy systems challenges in Scandinavian culture.	Seven	Digitalization and the energy transition; Smart grids; Smart metering and smart devices; Demand-response energy systems; Carbon, discourse and institutional lock-in; Big data analytics; Scandinavia culture; Surveillance capitalism.	John Rawls; Shoshana Zuboff; Performativity; Diffraction; Habitus; Social Capital.	Energy experts´ ethical perspectives, e.g. morals, trust, justice, and fairness. Role of energy experts´ perceptions of their products in the transformation of sustainable energy systems.

CHAPTER 3. METHODOLOGY

This chapter presents the methodology adopted to obtain the results of chapters 4-7 and resolve the research questions. As introduced in the previous chapters, the thesis context is the climate change problem and the socio-technical sustainable energy transitions. The theoretical framework was situated across posthumanism, social capital and habitus. Due to the highly interdisciplinary nature of my research, I adopted a mixed-method approach for data collection and analysis.

This diversity of areas and topics are reflected in the research articles in the appendix, including published, submitted and preparation articles. The results chapters present complementary discussions and analyses. To help readers understand the structure of the thesis, figure 5 depicts how the research questions are discussed across the following chapters.

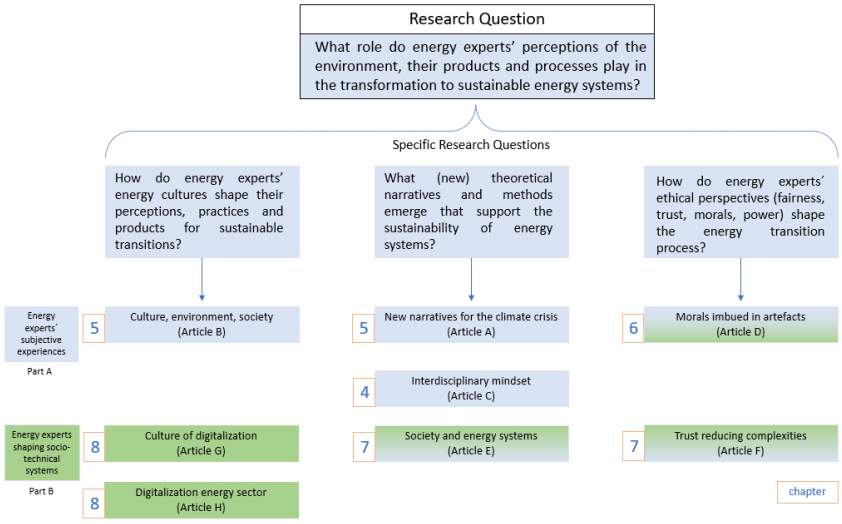

Figure 5. Relationship between research questions and chapters in the dissertation.

In what follows, section 3.1 situates the research context of my PhD as part of research as an ethnographer on the respective training network. Section 3.2 dives into those aspects of the ENSYSTRA that were explored in my thesis. Section 3.3 presents the

cases explored from the NSR. Section 3.4 describes the data collection methods, and section 3.5 details the data insights.

3.1. SITUATING THE RESEARCH CONTEXT: THE ENSYSTRA PROJECT

I study the energy experts´ perceptions starting from the network formed by the Energy Systems in Transition (ENSYSTRA[16]) project. ENSYSTRA (2018) is a Horizon 2020-funded project[17], linked to the programs of "*Excellent Science of Marie Skłodowska-Curie Actions" and* "*Fostering new skills by means of excellent initial training of researchers"* (MSCA, 2017)[18]. The project, conceived by senior researchers of the North Sea Region, had the primary goal of training ESRs to work in the energy sector´s decarbonization. In addition to forming energy professionals with a holistic view of sustainable energy transitions, ENSYSTRA was aligned with the European Commission's research strategy of pushing for more regional and intersectoral cooperations and partnerships[19]. As a result, it aimed to be an innovative interdisciplinary, intersectoral and international training network that would break down barriers between academia, industry, society, policy-makers, and research disciplines (ENSYSTRA, 2018). Specifically, the objectives of ENSYSTRA were:

> *"1) to develop state-of-the-art science for energy systems transition, scenario analysis and energy modelling tools with emphasis on interdisciplinary model collaboration.*
>
> *2) To provide ESRs with interdisciplinary, inter-sectoral and applied perspectives on the energy transition.*
>
> *3) To provide ESRs new skills and competences for interdisciplinary analysis.*

[16] See the official ENSYSTRA project website for more information: https://ensystra.eu/about-the-project/ Accessed on 04th March 2021.

[17] See more in https://cordis.europa.eu/project/id/765515 accessed on 12th March 2021.

[18] See more in https://trimis.ec.europa.eu/programme/excellent-science-marie-sklodowska-curie-actions accessed on 12nd March 2021.

[19] See more about European partnerships plans of the Horizon Europe in https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/european-partnerships-horizon-europe_en accessed on 04th March 2021.

4) To establish collaboration between key universities and their networks.

5) To create and increase linkages between different academic disciplines, applied research, industry and the public sector,

6) To develop links and synergies between relevant scientific arenas, and

7) To contribute to accessible energy science based on open source work environments." (ENSYSTRA, 2018 p. 3)

The project structure consists of six universities in the NSR: University of Groningen; Aalborg University; University of Edinburgh; Europa-Universität Flensburg; University of Stavanger; and Chalmers University of Technology. As well as 23 third parties from industry and non-academic institutions. Those institutions conform the environment for training the 15 ESRs to become interdisciplinary energy experts. Thus, the training was done as a collaboration between the network of academic and non-academic partners. While the universities provided the research structure and training on a PhD level, the respective third-party institutions hosted the ESRs during 3 to 11 month-long internships. This process was also aimed at strengthening the ties between the industrial, academic, and governmental bodies involved in the project. This was done in practice by the ESRs getting insights from those partners to drive and build theoretical, computational, mathematical or socio-economic models aimed at developing strategies to transform the energy system landscape in the NSR (ENSYSTRA, 2018).

Another characteristic of ENSYSTRA was that the experts who envisioned it, had an awareness that, due to the complexity of the energy transition, a holistic rather than a fragmented perception of the energy problem was needed. Thus, the project trained all experts in technical sciences, political sciences, social sciences, and the humanities. Building such a foundation of experts with knowledge in several fields was also believed to be necessary for developing interdisciplinary knowledge (Sovacool, 2014).

As a training network, the methodology developed in the ENSYSTRA project was an innovative strategy to form energy experts in accordance with the areas of technology, actor behavior and governance, considered as the main drivers of the energy transition (Figure 6). Thus, the project was divided into four work packages:

- Energy system modelling.
- Technologies and development pathways.
- Actor behaviour and interactions.
- Policy and market design

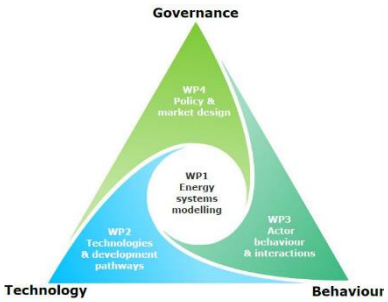

Figure 6. Relation between the four work packages of the ENSYSTRA project and the drivers of the energy transition (ENSYSTRA, 2018).

Considering technology, behavior and governance as the pillars of the energy transition is innovative in the sense that it brings those disciplinary fields to interdisciplinary encounters. This allows for searching integrative perspectives to deal with the challenges of adopting sustainable energy systems and contributing for addressing the climate change problematic. Such research pilot projects are a rich environment where scientific facts and other outcomes are the product of, and produce a society (Jasanoff, 2017). In the next section, I detail the ENSYSTRA project's relevance for my PhD thesis.

3.2. ENSYSTRA PROJECT IN MY RESEARCH

Having set the ENSYSTRA project as context, I will now present how its characteristics had an impact on my research:

- **Intersectoral collaboration**: the ENSYSTRA network opened access for interviewing `elite´ groups in the energy sector, for example, local politicians, researchers, energy companies and industries. This was an opportunity to learn about the practices of energy experts in relation to the organizations they belong to and work for, to the products they propose for

society and to how they perceive their environment. In this way, the ENSYSTRA network served as a means of comprehending the underlying structure of socio-technical energy systems as well as the perceptions of energy experts when envisioning the energy transition. Such characteristics compose the results that I will present in chapters 5, 6 and 7.

- **Socio-cultural perspective on energy research:** adopting the perspective of Bruno Latour (2005) on the analysis of scientific practices, the ENSYSTRA project can be considered as a living laboratory, an ideal space to study the scientific practices and the outcomes for society. The ENSYSTRA project configures a centre of power, representing many levels (international, national, and local) and organizations (European Union, organizations partners of the project, research laboratories). Thus, it was an ideal case study for revealing the ideologies and cultures that researchers are experiencing and the outcomes that contribute to energy systems' transformation. Furthermore, it revealed how the ESR´s mindset was being shaped by the socio-cultural environment they were immersed in, since the scientific study of the world is inseparable from the organization and scientists' activities (Lemke, 2001). Given the immense possibilities and aspects for analysis, I focused on understanding the research culture emerging due to the need for interdisciplinary energy research (next section).
- **Interdisciplinary cooperation:** As an insider participant in the ENSYSTRA project, I actively engaged in interdisciplinary energy research production, the results of which are reported in chapter 4. I also traced the practices of interdisciplinary knowledge production from the ESRs, and observed the network of actants in the project, and their/our practices of exchange and translation of knowledge (Latour, 2005). The interactions of energy experts consisted of actively communicating approaches and findings to other actors to understand the possibilities of crossing disciplinary boundaries. In this living laboratory, scholars were engaging with scientific facts, envisioning possible scenarios for energy systems, and finding their/my role in influencing the decisions and knowledge for tackling climate change.

- **Secondment partners:** My thesis's central focus emphasises the role of the perceptions of energy experts. Secondment partners provided access to investigating the energy experts' energy cultures in the NSR. The ENSYSTRA project facilitated my access to an energy producer and provided company. There I could apply ethnographic methods and semi-structured interviews energy experts considered from an elite group. Similarly, the academic secondment partners allowed us to understand the shaping of research cultures on the practices of the ESRs.

3.3. CASES AND EXPLORED ASPECTS OF THE NORTH SEA REGION

As exposed in the previous sections, the context (section 3.1) of this thesis influenced the selected cases explored. The use-cases were selected based on the potential of contributing to the research questions and to the overall understanding of the narratives needed to overcome the challenges brought by climate change to the energy sector experts. The research of this thesis is the result of an interdisciplinary exploration. Each use-case explored provided insights that allowed to answer the research questions from a holistic perspective. The thesis results are split into two main parts. Part one focuses on exploring the energy experts' perceptions, values and practices. Part two focuses on understanding the socio-technical systems from the perspective of the energy experts.

More specifically, part one is particularly focused on:

- *Energy cultures emerging from energy research practices*: The interdisciplinarity characteristic of the ENSYSTRA project was a living laboratory adequate to build new knowledge on how to develop interdisciplinary energy research. Understanding how to integrate different perspectives is a relevant part of restructuring energy research and forming experts with an interdisciplinary mindset. Interdisciplinary practices on the ENSYSTRA were traced, documented and a framework to enhanced cooperationg between scholars was proposed in chapter 4.
- *Environment-energy-society matters*: NSR energy companies deal with energy production and provision while having the challenge of

decarbonizing the energy sector and adapting energy systems accordingly. The perceptions of experts about energy resources potentially influence how they deal with environment-nature-culture matters. I explore those perceptions of energy experts in chapter 5.

Part two focuses on socio-technical configurations, in particular:

- *District heating systems (DH)*: the choice of studying DH systems was influenced by the following factors. First, the emissions produced by the heating sector in the NSR are responsible for half of the emissions of the energy sector in that region. Second, DH systems are socio-technical configurations, developing behavioural aspects and institutional configurations are as relevant as technical developments. This use-case allowed to study a socio-technical system as an entangled energy system. Such development requires the alignment of socio-technical factors, thus, understanding experts' narratives contribute with holistic views of those systems. Third, the research was carried out following an interdisciplinary cooperation with my colleague from the field of Energy Planning, enabling interdisciplinary research within the ENSYSTRA Project and expanding our expertise in the energy transition towards a more holistic understanding. Fourth, studying DH allowed me to explore socio-cultural aspects of the Scandinavian culture (chapter 6).
- *Digitalization of the energy sector*: a central part of the energy transition is the digital layer added to energy production, distribution and transmission infrastructure. Digitalization is considered to play a key role in transforming the energy grid toward smart energy systems. However, such change is also linked to the tendency for ubiquitous computing. This brings changes for the whole of society, meaning that the advancements in technical solutions need to be accompanied by advancements in legislation and regulations that protect citizens' rights to privacy. The choice of exploring the digitalization of the energy sector was to situate those changes into the domain of socio-technical systems, understanding such transformations as an entanglement of social and technical factors (chapter 7).

3.4. MIXED METHODS OF DATA COLLECTION

As an insider participant of the ENSYSTRA project, I got an “internalist” understanding of the energy experts' energy cultures in the energy transition of the North Sea (Ihde, 2009 p. 6). The internalist perspective comes from being an ESR in the project where I was being trained to become an energy expert and from a disciplinary background in engineering and science communication. Such characteristics allowed exploring the energy experts' proposal in-depth by engaging with the knowledge production for the energy transition in practice. The methods for data collection are connected with my embodiment and active participation in the project. Consisting of a mixed method approach composed of ethnography, observations, semi-structured interviews, questionnaires, and engagement in group discussions.

According to Mark Newman (2017), understanding science can be approached in two main ways: focusing on the explanation of some phenomena or focusing on the theory used to understand the phenomena. Similarly, in this thesis, two main interdependent approaches were taken when understanding the energy experts´ narratives for the energy transition. The first was to understand the phenomena of energy transitions. Its causes, motivations, and transformations the transition is generating. For example, the energy research cultures (see more in chapter 4). The second focus was on understanding the theoretical perspectives, structures, methods and techniques contributing to the transformation of energy systems. For example, the exploration of the digitalization of energy systems in chapter 7 was through in-depth analyses of the computational methods for research for protecting customers´ privacy. Those were carried out to understand the causal link between knowledge produced in laboratory and the transformations that provoke in societies. The dynamic of data collection was influenced by the context provided by the ENSYSTRA project (see details in section 3.1). Details on the adopted research methodology of mixed data sources are provided in the following sections.

3.4.1. ETHNOGRAPHY IN/WITHIN THE CASES

Ethnography consists of a qualitative research method of data collection based on observation of everyday practices and providing detailed and in-depth descriptions and analyses (Smith & High, 2017). In this thesis, ethnography was carried out to observe energy experts' practices in diverse environments and case studies (as described in section 3.3). The insights acquired through ethnography complemented other data sources for most studied cases. As a result, ethnography contributed to a holistic understanding of energy experts' environments, cultures and how their environments contribute to forming their perceptions about the transitions in the energy sector. Ethnography also favoured the understanding of energy experts´ ethical judgements and how those influence their practices and habitues (Smith & High, 2017).

Furthermore, autoethnographic accounts allowed me to reflect on the methodologies and theories in engineering and how those drive the underlying practices in science. Autoethnography is the method for accounting personal experiences to describe cultures, experiences and practices (Adams et al., 2017). Since the method represents a “socially-just” and “socially-conscious” act, it is a form of revealing cultural experiences (Ellis et al., 2011 p. 273). Thus, autoethnography as a method in this thesis allowed self-reflection on my practices and experiences in energy research while immersed in the energy experts' energy culture.

Ethnography methods can be interpreted as advancements in qualitative research methods (Lupton, 2019). Since, as a methodological tool, observing people's practices allows approaching human subjectiveness and embodiment. This aligns with the post-qualitative awakening of methodologies, which requires considering the diverse objects and subjects in the assemblages and the collective engendering of differences (Wells, 2021). Interviews, conventionally used as qualitative research, do not account for the materials or what contributes to such materialization. Ethnography fieldwork, on the other side, provided modes of accounting for phenomena, thinking, and inquiring about reality.

Furthermore, ethnography methods allow the adoption of diverse sources of data collection and diverse ways of doing analysis. Hence, it can complement traditional qualitative methodologies, such as interviews. The complementary methods approach for data collection and analysis chosen in this thesis, had the purpose of addressing methods limitations and eliminating the biases following a unique methodology that can introduce in the research outcomes (Choy, 2014). See in the next section how I carried the observations for data collection.

3.4.2. OBSERVATIONS

A complementary approach to traditional qualitative research, which mainly relies on interview and survey methods, is the use of observations. Karen Barad (2007) argues that words provide descriptions, which are representations of reality, and observations have the "power to reveal pre-existing properties of an observation-independent reality" (p. 195). Similarly, Yi-Fu Tuan (1977) argues that understanding through an experiential perspective is a process where seeing and thinking are closely related. He observed: "in English, "I see" means understand" (p. 10). In this way, the process of observing reality and acquiring knowledge through embodied experiences of the energy experts´ environment was done throughout the fieldwork. Fieldwork can be divided into three main grounds: ESRs' experiences in summer schools and workshops of the ENSYSTRA projects, ESRs in their natural environment (university they belong to and work daily), and industrial settings where energy experts work. The experiences acquired through observations were valuable to get a sense of those experts' cultures and understand the importance of the environment on energy experts practices. Data collected through observation had unique characteristics, and those details greatly shaped my research outcomes since seeing is a "selective and creative process in which environmental stimuli are organized into flowing structures that provide signs meaningful to the purposive organism" (Tuan, 1977 p. 10).

3.4.1. INTERVIEWS

Semi-structured interviews with energy experts were conduted to verify information acquired through literature review and observations. Since the dialogue and

knowledge are co-constructed between the interviewer and the interviewee, the choice of semi-structured interviews instead of structured interviews allowed to adjust the process to acquire the intended information (Holstein & Gubrium, 1995).

The structure of the ENSYSTRA project provided access to so-called "elite" groups. Since the term elite varies from the context and field of study (Smith, 2006), in my research, elite groups are considered experts in the energy field, experts working in energy companies or institutions from the NSR in diverse sectors and contexts. The adoption of interviews with elite groups was favourable since these allowed me to collect specific information that developed my research enquires and clarify questions resulting from information collected from other data sources (Goldstein, 2002), producing a holistic view of the energy culture of the NSR. For the interview process, I prepared a template for each group of experts with main topics and research questions based on previous knowledge acquired through other data sources. One of the group interviews was carried in cooperation with a colleague (chapter 6), in this case we both attended and performed the interviews. She was leading the main questions, and I took the role of taking notes and asking secondary questions when necessary. Interviews were recorded, transcribed and analysed.

3.5. OVERVIEW OF DATA COLLECTION

Table 2 shows the relation between the diverse methods, data sources, and the result chapters.

Table 2. Overview of data collection.

Method	Data Source	Chapter
Observations in workplace	ENSYSTRA Events: summer schools and workshops.	4
	Energy provider and producer company from NSR.	5
	ESR´s academic institutions.	4
Expert interviews	ESRs academic institutions.	4

	Energy provider and producer company from NSR.	5
	DH experts, researchers and regulators.	6
Systematic literature review	Scientific articles, book chapters, reports,	5, 6, 7
Questionnaires	Open-ended questions for the ESRs experiences when collaborating.	4
Autoethnography	Research practices, Scandinavian culture, interaction with energy experts.	4, 5, 6, 7
Fields notes	ENSYSTRA meetings, summer schools and workshops, and ESRs' main academic institutions.	4
	Meetings, and daily activities in the company.	5
Collection of materials	Internal data produced in the ENSYSTRA project. Energy company blog posts, projects descriptions. DH association regulations, record of customers complaints.	4, 5

3.6. ETHICAL CONSIDERATIONS AND IMPLICATIONS

This thesis potentially deals with sensitive information. Thus, ethical disclosure agreements were signed with the participants of the research. Ethical approval was obtained from Aalborg University. When research and observations were carried out at the Norwegian energy company, I signed a non-disclosure agreement as a requirement of the company to protect their confidential information. Such agreement influenced the research and the questions asked during the interviews, such that discussions about business strategies and company positions in energy markets were not discussed nor shared. Furthermore, I utilized anonymity and pseudonymization

techniques in relation to this organisation's data (such as not disclosing the company name and using a replacement name for the interviewees).

SECTION 1: Energy Experts´ Subjective Experiences

Energy experts' subjective perspectives are acquired through sensations. On the other side, objective views of reality emerge from energy experts' thoughts. Thoughts and sensations lie in opposite extremes of experiences, but “both are ways of knowing” (Tuan, 1977 p. 10) and can influence each other. This first part of the thesis maps, characterizes, and analyses energy experts´ practices. A necessary step to reflect on energy experts' experiences and internalized structures (Bourdieu, 1990), that is the purpose of this first part of the thesis. Energy experts´ experiences contribute to the practices on the energy transition and form their perceptions about the processes, their environment and their roles in the energy transition.

Chapter 4 focus is on the collaborative practices in energy research transitions projects. I investigate how energy experts perceive disciplinary boundaries and the role of institutional culture in the training. Chapter 5 explores the energy experts' views of their environment, nature and culture. I also explored how their perceptions influence the outcomes of their projects in sustainable energy transitions.

CHAPTER 4. (INTER) DISCIPLINARY ENERGY RESEARCH

This chapter analyses the shaping of academic energy experts embedded in specific institutional cultures. This is because academic culture impacts the research design and its outcomes. I focus on the practical challenges of designing pathways to develop an academic culture of collaborative energy research from disciplinary traditions and boundaries that underlie energy research. Disciplinary boundaries are considered here formed by material-discursive practices since the materials and discourses are entangled and jointly influence research outcomes (Barad, 2007) and can be a form of preserving those boundaries. Disciplinary boundaries are also considered disciplinary habitus. Interdisciplinary, multidisciplinary and/or transdisciplinary research setups should invite disciplinary experts to cooperate and re-think existent traditional boundaries and their limitations for generating energy research outcomes. However, this requires scholars to be exposed to other disciplines and research environments. Which promotes the reflection on their methodologies in order to consider the place for insights from other disciplines or to build new theoretical narratives for complex problems such as the climate emergency.

This chapter is presented as a four-fold examination of different practices and experiences encountered in the ENSYSTRA project to

1. Explore the energy experts´ narratives and perceptions of the process of energy transition research.
2. Identify lock-in practices of disciplinary habitus to expand the views on interdisciplinary challenges in practice. The lock-in terminology in economics implies a customer dependence on a product or service. Here it intends to frame how disciplinary habitus can work as lock-in practices (where the research structure creates areas of dependency), hampering interdisciplinary encounters.

3. Reflect on disciplinary energy research considering an iterative production of boundaries[20] between epistemological and organizational factors.
4. Understand pathways to boundary-crossing between disciplinary research while proposing a framework to improve interdisciplinary practices.

Those insights are based upon my report[21] to the REA entitled "*Model collaboration for energy systems in transition projects*" in Appendix A. In the report, I investigated the methodological and organisational lessons and challenges of the practices of disciplinary, interdisciplinary, multidisciplinary and transdisciplinary energy research based on the experiences of the 15 ESRs of the ENSYSTRA project. Furthermore, my article, co-authored with colleagues[22] and entitled "*Reflection through diffraction: Interdisciplinarity in energy science"* (Godoy et al., 2022), proposes a framework for developing interdisciplinary practices in energy research. The framework was built with theoretical and methodological insights from diffractive reading (detailed in section 2.5) and allowed an understanding of each other's disciplinary fields through the patterns produced by the encounters of disciplinary boundaries (Barad, 2007).

In the following section, I present detailed insights on the relevance of interdisciplinary energy research and how these are aligned with posthumanism (presented in section 2.1) and disciplinary capital theory (presented in section 2.7).

4.1. HOW CAN INTERDISCIPLINARY PRACTICES FAVOUR A JUST ENERGY TRANSITION?

The complexities of transformations in the energy sector arising from the climate crisis necessitate 360-degree perspectives in thinking about energy systems to account for the injustices associated with energy in society. The future of energy research is, thus, to be interdisciplinary and transdisciplinary. Caterina Pizanias (1996) enquired, "has the time come to rethink the limitations of disciplinary boundedness?" (p. 653). In this regard, it is reasonable to assume that disciplinary loyalties are to be abandoned

[20] Also called a "dynamic relationality", used in the diffractive methodology (Barad, 2007 p. 93).

[21] A mandatory deliverable of the ENSYSTRA project.

[22] Co-authors: Kathrin Otrel-Cass, Leire Gorroño-Albizu, and Jinxi Yang.

or at least rethought, resulting in the distancing from more conservative elements (Wong, 2016). A primary justification is that transcending anthropocentrism (as explained in section 2.1) requires contemporary interdisciplinary research practices with enough robustness to challenge the current structural elements of our institutions and pedagogical practices in sciences and humanities. According to Rosi Braidotti (2013), the proliferation of new discourses that favour a critical perspective on disciplinarity, particularly in relation to traditional organisations of the university and departmental structures, requires methodological and theoretical innovations. At a research level, the integrative character of interdisciplinary research allows for generating a new level of discourses, integrating knowledge from several disciplines while building bridges between generalized concepts and causalities (Schuitema & Sintov, 2017). Thus, interdisciplinary thinking and tools are to be developed to deal with the energy transition challenges that, by their nature, involve areas of origin that are technical, social, technological, economic, and political, among others (Schuitema & Sintov, 2017).

Academic culture and research practices are segregated. Researchers tackle problems coming from common backgrounds and bits of knowledge in disciplinary encounters, forming and reinforcing disciplinary communities. The methods and theoretical approaches in those practices stay within the same disciplinary boundaries to refine basic or fundamental knowledge (Van Rijnsoever & Hessels, 2011). While in multidisciplinarity research, the topic is of common interest, and the perspectives of the researchers will juxtapose (Klein, 2014). Meanwhile, interdisciplinary interaction integrates and synthesises disciplinary insights (Danermark, 2019; Klein, 2014). Also synonymous with teamwork, interdisciplinarity creates application-driven knowledge based on insights from various disciplines (Van Rijnsoever & Hessels, 2011). On the other side, transdisciplinarity is where research outcomes transcend, transform and transgress boundaries (Klein, 2014). To Karen Barad (2007), the production of boundaries between disciplines occur as a set of material-discursive practices. To her, this is a question of transdisciplinary matter and being attentive to details can foster constructivist arguments for reworking disciplinary boundaries. Based on these arguments, we can deduce that the transformation of energy systems can benefit from

transdisciplinary practices due to its unique capability of generating research outcomes that transform disciplinary boundaries.

Posthumanism scholars greatly contributed to the advancements of more than mono-disciplinary research. They have progressed in thinking about methodologies and disciplinary structures presented in institutions. Partially because posthumanism recognizes the agency of other species in producing knowledge towards new ways of knowing (Ulmer, 2017), allowing an open approach in relation to research boundaries. Thus, posthumanism offers novel methods for accounting for material, ecological and geopolitical injustices (Ulmer, 2017). As an interdisciplinary field, posthumanism includes the perspectives of several disciplines, and its novelty is highly required and aligned with the nature of the problems in energy transitions. Posthumanism encourages the development of interdisciplinary and transdisciplinary pedagogical steps because the starting point of inquiry in posthumanism is from the real-world problems to their solutions, rather than more abstract and generic endeavours conventional in basic sciences. Similar approaches are adopted in institutions that use the methodology of problem-based learning (PBL) (Fladkjær & Otrel-Cass, 2017). Furthermore, application-driven research outcomes can be an opportunity to address some of the status quo problems, like power and resources concentration, emissions imbalances between the global north and global south, and responsibility for the climate change consequences (already discussed in section 1.2).

As previously discussed, the need to re-conceptualizing the Anthropocene is pushing for new concepts and analytical frameworks, such as those that can be achieved through interdisciplinary collaboration (Brondizio et al., 2016). It has been argued that while disciplinary technical thinking alone may lack the robustness required to deal with ethical issues of climate change and energy systems, interdisciplinary and transdisciplinary approaches can meet the requirements of building new ethical frameworks (Braidotti, 2013). Advances in this direction are reflected in academic practices, where the calls for departments to collaborate are getting louder, funding agencies are supporting projects intended to produce interdisciplinary knowledge, and researchers are awakening to the need for collaboration. However, those aspects are

still insufficient to generate the conditions for interdisciplinary outcomes (Van Rijnsoever & Hessels, 2011).

Methods, theories, evaluation systems and ethical frameworks need to tackle problems like disciplinary lock-in, disciplinary habitus, and academic capital accumulation. Academic capital is the set of norms, beliefs, and rules on academic culture. Academic capital can be a barrier to interdisciplinary research since institutions' capital cultures reside in disciplines where monetary and fiscal resources are distributed based on a definition of the essence of a faculty's work (Bieber, 1999). In science and technology departments, the search for capital frequently leads to the commercialization of research outcomes, which gives an accumulative advantage to those fields, and the research outcomes become an integral part of economic growth. However, this disciplinary lock-in of academic capital is not easy to solve because research grants and capital distribution to departments generate an accumulative advantage, where departments get richer in terms of symbolic and material capital (Mendoza et al., 2012). Those disciplinary traditions (or disciplinary habitus) are in place, strongly hampering the advancements of interdisciplinary cultures and the daily practices of scholars who wish to advance interdisciplinary research. The problem brought by those factors is that since interdisciplinary and transdisciplinary research are key for addressing current problems, the opportunity to rethink energy systems beyond the status quo can be hampered if disciplinary fields and scholars maintain resistance.

A consequence of mono-disciplinary research outcomes and departments' cultures centred on technological research projects is that they can be limited in provoking changes in societies' energy cultures. This is because, often, the environment of laboratories is symptomatic of how a technology or the culture around specific technologies resulted in a narrow focus for the technology development, which is often associated with a disinterest in how technologies become embedded in society (Sørensen, 2013). Such intellectual knowledge disconnection from the social, political, and cultural contexts in scientific research has been challenged in the history of science, e.g. by the works of Bruno Latour, 2005 and Michael Lynch & Steve Woolgar, 1990). However, much progress still needs to be made. In this way,

understanding the emergent practices of a technological research project improves the direction of scientific knowledge production, impacting non-human agents such as policies, society participation and community engagement (Sørensen, 2013). This requires viewing the science practices and research as a human social activity conducted with institutional and cultural structures (Lemke, 2001). This means seeing the scientific study of the world as itself inseparable from the social organisation of scientists.

To Bruno Latour (1996), when scientists and engineers speak in the name of new objects or structures, for example, the “energy transition”, their descriptions of facts and machines are the same as describing the people they enrol and encounter. Similarly, as this chapter unfolds the interdisciplinary energy research, I was not interested only in the material produced and the scientific facts but in the practices, the experts engage in and the emerging new habitus. As Karen Barad (2007) proposes regarding the diffractive methodology, “it does not take the boundaries of any of the objects or subjects of these studies for granted but rather investigates the material-discursive boundary-making practices that produce "objects" and "subjects" and other differences out of, and in terms of, a changing relationality” (p. 93). Thus, instead of looking at the final products as black boxes (Latour, 2000), I was interested in the mutual engagement of materials and discourses, objects and subjects, the types of outcomes produced and their pathways and different engagements.

My main justification for the research advanced in this chapter is that more than mono-disciplinary encounters favour the distribution of academic capital, induce scholars and departments to change their disciplinary habitus, and avoid disciplinary lock-in effects. I also argue that the path to reorganizing research in universities begins with developing professionals with interdisciplinary mindsets and capabilities. Those outcomes were built based on the ENSYSTRA project (detailed in the methodology, section 3.1.2), which was built to produce knowledge of interdisciplinary nature. I took the ENSYSTRA project as an opportunity to observe collaboration in practice, which serves as a case of study in this chapter; details about the role of the project in my research are in the methodology (section 3.2.1). In the following section, I explain

my approach to researching collaboration practices and the specifics of the energy research context for the study case in this chapter.

4.2. THINKING THE PRESENT: INTERDISCIPLINARY PRACTICES IN THE ENERGY RESEARCH

In the previous section, I discussed the possibilities that more than mono-disciplinary research can bring to society, the challenges underpinning mono-disciplinary research in institutions' cultures, and the relevance of looking at scientific practices for developing a just transition based on an interdisciplinary mindset. This section discusses this chapter's object of study, the ENSYSTRA project's interdisciplinary research, and the practices emerging from the encounters of disciplines in energy research fields. ENSYSTRA project can be considered a living laboratory. Following Bruno Latour´s (2005) analogy, laboratories are learning networks, where the learning goal of the participants is developed through the engagement of human and non-human actors that exchange and translate knowledge (Lafton & Furu, 2019). From this perspective, humans and non-human elements conform to the ENSYSTRA project. Such an environment enables tracing and documenting contemporary practices of disciplinary, interdisciplinary, multidisciplinary and transdisciplinary energy research, allowing to see traces of disciplinary capital on the institutions and researchers, as well as how those are transformed into habitues (Pizanias, 1996). Furthermore, because the project's goal was to conduct interdisciplinary energy research, it allowed for "thinking of the present" of contemporary energy research (Braidotti & Butler, 1994, p. 35). The context of "thinking the present", which those authors referred to, is about the conservative academic cultures that are still monopolized by disciplinary boundaries and allow little connection from theory to practice (Braidotti & Butler, 1994). The context of thinking present in my thesis is built upon interdisciplinary energy research as a process of making sense of the changes in energy-society matters and contributing to the dynamics of the creation of new subjects of concern. New subjects, of course, require new social and symbolic structures, allowing individuals and structures to change and transformations to be registered collectively (Braidotti & Butler, 1994). Tracing and reflecting on the

individual stimulus for interdisciplinary encounters and the intra-actions in place can potentially transform collective disciplinary habitus.

The energy culture of the ENSYSTRA project recognized matters of concern regarding the energy transitions in the NSR. The project´s challenge was to design energy research strategies for this region to implement the transition from fossil fuels to an emissions-free energy system. This required discussing almost all the aspects of energy research. Thus, the areas covered by the project were social sciences, political sciences, economics and energy modelling. Across those areas, a team formed by 15 PhD researchers, professors, universities and third parties worked to design strategies for the transformation of energy systems. Each ESR worked on an independent doctoral research project, but, in totality, the group touched on almost all the aspects and challenges of the energy transition in the NSR.

Each ESR comes from a different disciplinary background, where 73,33% come from engineerings (including myself), such as mechanical, industrial, chemical, environmental, energy, and electronic engineering. 26,67% had a background in history, environmental sciences, urban design and planning, or meteorology. The ESRs also had different cultural backgrounds, a requirement of the MCSA program to train international citizens. In total, the project comprises ten different nationalities. Out of the 15, male scholars were 10 (66%), and female scholars were 5 (33%). The ESRs were tasked to contribute to their disciplinary field and collaborate and generate knowledge of interdisciplinary nature. The requirement of contributing to disciplinary fields, is per se a constraint to fully engaging in interdisciplinary inquires. Scholars' need to generate disciplinary knowledge is linked to structural factors (culture of the research groups they belong to), personal choices (e.g., perceptions that a disciplinary field guarantees specific jobs or brings more specialized knowledge), and many others. Furthermore, ESRs must integrate insights from third parties and produce global research results while researching the context of the NSR. The project´s structure and training consisted of several different activities, as detailed in Table 3.

Table 3. Activities carried out during the four years of the ENSYSTRA project.

Activity	Topics covered	Number of events/period
Workshops	Context of the North Sea Region; Energy economics, markets, investments, and business; Modelling energy systems; Technology and innovation for renewable and low carbon energy.	4/a week each
Summer Schools	Interdisciplinary modelling; Energy laws, policy, planning and governance; Energy cultures, participation and customers interactions.	3/a week each
Internships (Secondments)[23]	Understanding the practices of energy experts from academic and third-party organizations; Mapping energy cultures in those environments of the NSR; Gaining research experience.	4/9 months in total
Conferences (Open to the public)	Sharing research outcomes from the energy transition of the NSR.	3/a day each

[23] Based on my experience, each ESRs had differente settings.

Workpackage Meetings	Cooperation; Deliverables Coordination; Progress monitoring; Feedback; Interdisciplinary collaboration; Coordination of presentations.	9/1 to 5 hours each
ESRs Meetings	Issues of concern; Questions to be raised to the NMB meetings; Coordination of deliverables.	9/1 to 2 hours each
Network Management Board (NMB)	Monitoring of project progress; Deliverables; Ethical issues; Review deliverables; Training and dissemination; Financial aspects; Secondments, etc.	Monthly (96)/1 hour each
Deliverables for Funder (REA)[24]	Research Proposal; Career development plan; Research articles; Posters; Policy briefs; Conference papers; Industrial and policy meetings; Open-source modelling infrastructure database; Quantified roadmaps; Best practice guidelines[25]; Articles for industry and general audiences; Policy strategy framework; Data management plan; Project website.	29/diverse durations

[24] The deliverables were responsability of the ESRs, some of those, e.g. six policy briefs, were produced as collaborative practices among the ESRs.

[25] Under my responsability and part of the analysis of this chapter (Appendix A)

As the project is a robust structure of many activities and experts, many subcommunities were taking place. Observing those subcommunities (including my own work package in the project, Actors Behaviour and Interactions) allowed me to see the energy transition culture emerging from those laboratories. Also, considering that the emerging cultures are articulated across diverse heterogeneous subcommunities, individuals learn and enact specific complementary roles in those structures (Lemke, 2001). In this way, the analysis of the ENSYSTRA project practices reveals a rich environment for understanding contemporary practices in energy research. The research cultures of ENSYSTRA and its subcommunities were explored by tracing shared values and views constructed by the human and non-human actors in the project. Such an approach was fundamental for understanding the social, cultural, and economic context in which the energy transition is embedded and emerging.

The experiences reported in this chapter are based explicitly on my immersion in understanding the pathways for interdisciplinary research. Furthermore, it reflects the experiences of scholars in the ENSYSTRA project and the trajectory of collaboration practices in the project. As the project allowed my immersion in interdisciplinary practices, it complemented the construction of my interdisciplinary research background (BEng Environmental Engineer, MSc Science Communication, PhD Energy Sustainable Transitions). The reported experiences are as an insider researcher in an energy research project intended to be interdisciplinary while advancing interdisciplinary research in practice (e.g., cooperation with the work package and topics-wise, as seen in this thesis). In the next section, the performativity[26] of the researchers in interdisciplinary energy practices is presented.

4.3. PERFORMATIVITY OF AN INTERDISCIPLINARY ENERGY TRANSITION RESEARCH: SUMMARY OF THE APPENDIX A

Based on the report:

[26] Performativity means the material-discursive practices of the bodies that are interactively intra-acting (Barad, 2003).

Godoy, J. (2021). **Best practice guidelines for model collaboration**. ENSYSTRA project, REA.

The report presented in *Appendix A: Best practice guidelines for model collaboration* was an assessment of the status of collaborations in energy research and the ESRs' research culture they are immersed in. Such assessment was a mixed-method approach formed by ethnography methods, structured questionnaires, interviews and the experience of being an insider researcher in the ENSYSTRA project. The report, under my responsibility, was a deliverable of the project to the REA. The deliverable date was July of 2021. At this stage, most of the collaboration practices and encounters were in a finalized or advanced stage. The intention and purpose of this guide were to identify the challenges of sharp disciplinary boundaries (also called `habitus´ in my article (Godoy et al., 2022)) and to create guidelines for collaboration in energy research. Disciplinary culture is a characteristic of academic research culture, but the ENSYSTRA project's intention was to foster interdisciplinary research encounters. Those different purposes naturally produced tensions and influenced scholars' behavioural dynamics, influencing the researchers' practices and outcomes for the energy transition. The report traced and documented the pathways and practice of ESRs in non-mono-disciplinary encounters. In this section of the chapter, I expand the reflections, spotting onto-epistemo-logical aspects and the challenges, benefits and learning outcomes of the ESRs that influenced the project results from collaboration practices.

Therefore, the subject of study is the ESR's experiences of going through a process that I call “becoming energy experts”. This means being attentive during the period of 3 years to the ESR's experiences, including my own, revealing epistemological encounters, manifested inquires and challenges of collaborating in energy research. Thus, observing the practices of early-stage experts revealed how unstructured the projects become due to the lack of an understanding of how to develop interdisciplinary and transdisciplinary research. See how this applied to ENSYSTRA in the next section.

4.3.1. KNOWING AND BEING, ONTO-EPISTEMOLOGICAL ENCOUNTERS IN ENERGY RESEARCH

The onto-epistem-ology term, as explained in section 2.4, refers to the inseparability of ontological and epistemological matters. Accordingly, the analysis of interdisciplinary practices in energy research cannot be separated from epistemologies (the way we know) and ontologies (what things are). Specifically, this implies that when studying the practices of knowing and being, every specific intra-action matters. Thus, the research outcomes in energy research are mutually constituted by the scientific practices in themselves, but also by other practices, as well as characteristics of the ESRs, activities they are undergoing, materialities, methods, global events, etc. Many factors are in place intra-actively producing research outcomes for the energy transition. I have synthesised the outcomes of the deliverable in Table 4, presenting the onto-epistem-ological encounters on the ENSYSTRA project by summarising the disciplinary, multidisciplinary, interdisciplinary and transdisciplinary encounters held in the project.

Table 4. Synthesis of onto-epistem-ological encounters and collaborations developed during the ENSYSTRA project.

Research work package	Collaboration project description	Type of collaboration	Researched aspects of the energy transition	Intersecting areas	Outcome
Name: Energy System Modelling **Team Focus: integrated use and development of models covering all key energy supply options, energy carriers and the infrastructure.**	Integration of spatial and economic components of the energy model.	Interdisciplinary	Costs of offshore wind farms, e.g. maintenance and operation.	Spatial analysis, Economics, Energy system modelling.	Research Article (Gusatu et al., 2020)
	Investigation of how hydro storage, nuclear power policy, and sector coupling affect the cost of the future low-carbon European electricity system.	Interdisciplinary	Insights from nuclear power policy and sector coupling for modelling electricity cost.	Energy storage, Energy policies, Economics, Sector coupling.	Research Article (forthcoming)
	Critical power-to-heat (P2H) and thermal energy storage (TES) technologies review.	Multidisciplinary	Insights from biomass and hydrogen technologies (to model biomass-based CHP and Hydrogen storage).	Sector coupling; Technology assessment.	Interim report to the secondment partner TNO - Netherlands Organization for Applied Scientific Research
	Spatial and temporal analysis of environmental effects of offshore wind farms.	Multidisciplinary	Insights from the needs of the actors for designing shared used spaces for offshore areas.	Spatial analysis, Temporal forecasting, Environmental impact, Energy technologies.	Research article (Florentina et al., 2022)
Name: New Technologies and Development Pathways **Team Focus: analyse different technological**	Long-term cost reduction potential for offshore wind technology.	Disciplinary	Economic insights of the technologies learning curve.	Economic Analysis, Energy technologies.	Research article (preprint available in Santhakumar et al., 2022)

options for the future energy system.					
Name: Actors' Behaviour and Interactions **Team Focus: understand the drivers for energy system transitions through human behaviour and interactions.**	Perspectives on actors´ behaviour and their interactions in the context of sustainable energy transitions.	Disciplinary	Behavioural aspects of the energy transition.	Energy cultures, Ownership Models, Investments Decisions.	Annotated Bibliography (Godoy et al., 2020) and a research article (forthcoming)
	Institutional conditions for district heating companies' trustworthy behaviour	Interdisciplinary	Techno-economic and socio-technical, e.g. insights from cultural psychology.	Institutions and organizations; Behaviour; Cultural analysis; Socio-technical systems, DH systems.	Research Article (Gorroño-Albizu & Godoy, 2021)
	Experts' views on how to enhance consumers' trust in district heating.	Interdisciplinary	Socio-technical systems and cross-cultural analysis	Experts Behaviour; Socio-technical systems; DH.	Research Article (forthcoming)
Name: Policy and Market Design **Team Focus: understand the role of governance structures, including policy, regulation, and markets, supporting technological developments.**	Policy brief on interconnector expansion in the North Sea Region.	Disciplinary	Policy analysis	Interconnection expansion, Policy Analysis.	Project Deliverable for funder (REA)
	Quantified scenario Roadmap.	Interdisciplinary	Insights from energy modelling scenarios	Modelling, Interconnection barriers, Energy efficiency, Business models	Intern Report for funder (REA)

The synthesis presented in Table 4 shows a thematical analysis of the research practices within the ENSYSTRA team with a focus on the present complexities of academic culture and their structural traditions (such as disciplinary lock-ins). The analyses resulted in the following themes for interdisciplinary collaborations:

- *A pragmatic approach for interdisciplinarity:* Here, the outcomes were the drivers for collaboration practices. Table 4 shows that the researchers were tasked with set deliverables, typically detailed in the project proposal of the ENSYSTRA project, which followed the funding agency's requirements (Horizon 2020 and MCSA). The deliverables, such as policy briefs, integration of knowledge and presentations by the work packages, quantified roadmaps and reports for the secondment partners, requested the ESRs to work together. The approach adopted in practice in this type of interdisciplinary encounter can be considered of a pragmatic type. Based on "outcomes-centeredness", the researchers' practices integrated their knowledge from disciplinary fields towards an effective and workable final product (Mansilla, 2006, p. 3). Disciplinary inputs were strategically selected to comply with the requirements of the outcome. Although with this approach, researchers needed to be strategic about which insight each scholar/discipline contributes to the final research product, the outcomes were not of a transcendental nature, such as those that could be achieved through transdisciplinary research. However, the exposure (and requirements of collaborating) of ESRs to the practices of collaborating led to some outcomes where the intersection of disciplinary fields occurred (and some interdisciplinary encounters). For example, my research article exploring the cultural aspects influencing the planning of institutional factors for socio-technical systems is clear evidence of social sciences and energy planning integration (Gorroño-Albizu & Godoy, 2021). Those research inquires also allowed to create of new theories about the factors associated with the development of energy systems (see more in chapter 6).

- *Interdisciplinarity as social practices:* Caterina Pizanias (1996), inspired by the habitus concept and dispositions theories of Pierre Bourdieu, considers interdisciplinary research as a social practice where the embodied person is always in place in the production of outcomes. Thus, the proximity of scholars, in any sense (physical, gender, background or disciplinary closeness) favours the development of a propitious environment for collaborative practices. Contradictorily this can also induce research environments towards segregation. On the other hand, crossing disciplinary boundaries is tremendously demanding and subject to disciplinary/institutional domestication (Pizanias, 1996). In the ENSYSTRA project, I observed interdisciplinary research emerged from scholars working in the same work packages (e.g., scholars working in modelling or agent behaviour), having the same interests, or from the same organizations/universities. This was a factor that drove interdisciplinary encounters generating outcomes. However, those were often based on the juxtapositions of disciplines and inquiries alike. Another observation that highlights the ESR's social practices was when they had to reflect together (during events and workshops), including on the research culture, their disciplinary habitus and the material engagements to adjust to the project's interdisciplinary purpose and apply the received training. Orchestrating support for such social environments contributed greatly to energy experts exploring interdisciplinary practices (Stephenson, 2017) and to form energy experts with more than mono-disciplinary perspectives since:

  > "…scholarly inquiries are constructed in relationship with persons or text in the field that have had a direct role in opening or closing doors, maintaining boundaries, creating or solving problems, unearthing findings and contradictions." (Pizanias, 1996 p. 649).

- *Characteristics of scholars:* Frank Van Rijnsoever and Larurens Hessels (2011) previously observed that female researchers tend to be more engaged in collaboration practices compared with their male colleagues. This was also the case in the ENSYSTRA project, where 4 out of 7 interdisciplinary and

multidisciplinary research outcomes were led by female ESRs, and 5 out of those results had female scholars contributing. On the other hand, male scholars leading interdisciplinary and multidisciplinary outcomes were 3 out of 7, while they participated in 4 out of 7 research outcomes. Interdisciplinary research encourages focusing on marginalized issues and groups, and although the sample is not significant, gender factors can have a correlation on why inquiries of e.g., ethics and justice were barely covered (or only addressed indirectly) in the project. The diversity of backgrounds and nationalities of the ESRs had little (only indirect) influence on the practices of the project and on the research outcomes since ESRs mostly followed disciplinary practices. This could be partially attributed to the influence of a ‚longing' for scientific objectivity that fails to recognise issues of the ´body´ related to class, gender, race and privilege (Pizanias, 1996).

- *Instrumental role of sciences:* The European Innovative Training Network, through which the ENSYSTRA project was funded, has a tradition of approaching research and energy sciences as having an instrumental role. This is seen in the cooperative purpose with industries and non-academic partners and looking at the materialities being produced. The cooperative purpose tended to mutually develop the ESRs as well as the projects of the organization hosting the researcher towards strategies for the energy transition. This is reflected in the material aspects (deliverables, focus of research articles), where most of the purpose was on designing frameworks for institutions, creating political instruments, and modelling economic factors for the industry. Similar outcomes inform IPCC decisions, a problematic outcome since cultural and social aspects are resistant to modelling (Valtonen et al., 2020). An example of my research (chapter 6) focused on studying cultural traits that can lead to the development of fairer conditions for customers of DH systems. Such outcome also has an instrumental role in informing DH organizations on how to adopt strategies that lead to the cooperation of citizens to the decarbonization. However, as researchers, we have little control over whether the outcomes are used for

enhancing (in this case) monopolies control. But a critical effect of instrumentality practices on energy research is that it can jeopardize experts´ objectivity in relation to political and commercial interests. Preservation of non-instrumental functions, such as the "creation of critical scenarios and world pictures, the stimulation of rational attitudes, and the production of enlightened practitioners and independent experts" (Ziman, 2003). Researchers' ethical instances are primordial, not just when communicating the results. Because even if researchers follow the honest broker perspectives (Pielke Jr, 2007; Turnhout et al., 2013) when communicating outcomes for policy purposes, they can be susceptible to the powerful forces and habitus of the institutions they are embedded. Furthermore, moving the scientist practices from an instrumental role can contribute to advancing scientific facts that do not miss out on insights anchored in everyday life and other rationalities other than technoscientific (Ryghaug & Skjølsvold, 2021; Wynne, 1996). For example, energy solutions aimed at transforming the way we use energy in our houses without mobilizing insights about the lifestyle of householders (more on that in chapter 7) (Ryghaug & Skjølsvold, 2021).

- *Energy transition as a socio-technical problem:* The characteristics of most of the outcomes on the projects entail modelling techno-economic aspects, and few insights were included from other fields, areas or disciplines. Seeing the energy transition as a socio-technical problem can be a beneficial way of framing the energy sector's decarbonization since sociotechnical problems include disciplinary perspectives while maintaining theories and methods that are distinct from those of the respective disciplines (Büscher et al., 2019).

4.3.2. WHAT ARE THE CHALLENGES OF THE UNDERLYING LOGIC OF DISCIPLINARY FIELDS FOR INTERDISCIPLINARY RESEARCH?

The previous section discussed the research outcomes resulting from collaborative practices, analysing intra-acting factors that make those encounters possible (the likeliness of collaboration) or work as barriers in practice. In this section, I investigate

the ESRs' motivations, bottlenecks and learning outcomes of the collaboration practices carried out in the ENSYSTRA project, as represented in Table 5. Since the project was intended to produce knowledge of an interdisciplinary nature, the character of this innovative network is also susceptible to the emergence of challenges due to the complex nature of integrating multiple perspectives. The complexity stems from the aforementioned disciplinary habitus and the conflicting world views that emerge from interactions. Furthermore, experts' thoughts and perceptions of the environment they find themselves in influence their experiences and the process of becoming experts (Tuan, 1977). From a socio-cultural standpoint, the scientific study of the world is inextricably linked to the social organisation of the scientists' activities (Lemke, 2001). This means understanding the reality of science production by observing the "things-in-phenomena", where the discourse and the material have a dynamic of relations, reconfiguration, and entanglements that come to matter (Karen, 2007 p. 140).

Table 5. Synthesis of the ENSYSTRA ESRs motivations, challenges and learning outcomes from collaborating in energy research.

Motivations	Bottlenecks	Learning outcomes
• Expand the views on the complexity of the energy transition. • Gain a holistic approach to the energy transition problem. • Understand the driving forces that influence and impede the advancement of renewable energy development. • Applying interdisciplinary approaches for optimum energy systems management and to maximise energy utilisation, grid reliability, and resilience. • Improve the quality of the research outcomes, receive feedback and maximise available resources.	• Different disciplinary languages in each research field. • Challenging to align research questions. • Unclear benefit for all collaborators. • Finding a shared topic that fits the interest of multiple authors. • Different research practices hamper the relevance of addressing issues related to politics and policies. • Disciplinary theories and methodologies advocate for their particular views. • Knowledge gaps. • Dealing with different ontologies and epistemologies requires expertise in more than one field. • Management of workload: collaboration workload overlaps with the workload of PhD thesis, university requirements and ENSYSTRA deliverables. • Institutions keep incentives for individual/single author publication. • Incompatible university timelines, deadlines and research objectives.	• Collaboration contributes to understanding the energy transition from several perspectives, e.g., technical, market, social and policies, innovation, and project management. • Engaging in interdisciplinary teams helps to build bridges between different fields. • Interdisciplinary projects enhance the scientific knowledge of different energy-related fields. • Interdisciplinary projects help boost scholars' dissemination of disciplinary insights to various audiences. • Collaboration enhances open-mindedness and helps to review research design and refine research questions. • Observation of scholars' research design, data and approaches help to shift and adjust research focus. • Projects that strive for collaboration (like ENSYSTRA) require a coherent and straightforward strategy to obtain expected results. • Clarification about basic concepts is needed since researchers engaging in collaboration take the role of experts and beginners. • Awareness of the limitations of one´s understanding in other related disciplinary fields is required to build common grounds.

Thinking about the present, I analysed the ESRs' motivations for collaboration in energy research, where they can be divided into two categories:

- *Visionary expert perspective:* The first motivation is based on an intention of gaining interdisciplinary knowledge, which I consider to be a "visionary expert´ perspective". Words like "holistic", "expand", and "complexity" are used to describe the types of insights we envision that the collaboration process could provide. Such descriptions represent the formative process that the ESRs are undergoing, as well as the views that the ESRs have on what skills energy experts possess.
- *Disciplinary habitus:* the willingness to contribute to the knowledge in a disciplinary field drives collaboration. For instance, when collaboration is described by the ESR as fundamental for the "advancement of renewable energy" and "optimum energy systems management" (quoting ESRs words from Table 5). As a result, the ESRs see interdisciplinarity as a means of improving disciplinary knowledge. Such motivations for conducting interdisciplinary research can result in incremental innovations rather than a radical change in the system's status quo (e.g. in the academic structure or on how energy systems are perceived in society). Such deduction is contextualized by material-discursive practices analysis, inspired by the study of Tomas Skjølsvold (2014), where he proposes two ways of implementing technological transformations in society: translative and transformative. The ESRs energy culture, in general, is motivated and driven by translative developments, meaning that the culture studies specific technologies development or follows a specific approach of analysis, e.g. techno-economic analysis of the wind turbines. A transformative analysis will consist of ESRs culture being engaged in discussing the imaginary collective, symbolic and cognitive meanings of those technologies. Such practice can also work as means for disciplinary scholars to maintain an accumulative advantage, such as those of material capital (e.g. grants, funding) and symbolic capital (e.g. impacting the number of publications) (Mendoza et al., 2012). Although the ENSYSTRA project was designed with a balance of energy aspects to be researched, most of

the outcomes (as shown in Table 4) of the collaborations were from intersecting areas of knowledge, and few of those outcomes integrated knowledge from different areas of energy research (a critical issue in interdisciplinary research as described by Berth Danermark (2019)). This is problematic because the energy transition requires integrated and simultaneous technological advancements with the development of social norms, citizen engagement and ethical perspectives (Cohen et al., 2021). Furthermore, as Rosi Braidotti (2013) recommended, reinventing academic practices and creating new ethical frameworks are necessary to deal with the present challenges society faces, but how will it be possible to reinvent academic fields with the same practices? Is the limited scope of disciplines enough to provide holistic views to address the challenges of decarbonizing the energy sector with no further consequences, such as the creation of more inequalities in those systems?

Motivation and willingness to collaborate do not guarantee collaborations are happening. Collaborations' success depends on the characteristics of the created scientific communities, the insights shared by scholars and what material engagements happen under the carried scientific practices. In practice, the challenge for scholars is to work together, engaging in diverse environments of diverse cross-cultural and cross-sectoral scales. Through the in-deep analysis of the bottlenecks the ESRs faced for collaborating in the ENSYSTRA project, I synthesized the following remarks:

- *Disciplinary lock-in*: in the above section, disciplinary habitues worked as motivation for searching for interdisciplinary insights that can contribute to disciplinary knowledge. The challenge of such a perspective is that when scholars need to leave the core niche of research, they are used to (methods, practices), and new inquiries emerge. For instance, the ESR highlight that it was difficult to see the clear benefits of collaboration, find a topic of common interest or align research questions. Disciplinary lock-in mechanisms bring challenges to interdisciplinarity research. Scholars carry disciplinary habitus in their background, maintaining practices and habitus into niches through the application of methods, theories, and research approaches and having a tendency to solve

problems with the methods already known. When cooperating, scholars tend to use the language they are familiar with, which implies communication challenges for interdisciplinary encounters. In this way, disciplinary habitues and lock-in mechanisms are in place, and being conscious of those challenges can help scholars to develop practices that overcome those and advance interdisciplinary research.

- *Institutions habitus (Structural):* The difficulties of interdisciplinary research can reinforce and be reinforced by traditional research structure. ESRs reported that institutions incentivize single-author publications. This institutional barrier led scholars to dedicate less effort to generating interdisciplinary outcomes. Other issues, such as management of workload of the universities, different timelines and deadlines, create challenges that need to be addressed from an institutional perspective instead of being issues ESRs must solve.

The **learning outcomes** of collaborations reported by the ESRs in the structured questionnaires, observations through ethnographic methods and experiences as a project insider revealed three main themes that could be extracted from the data:

- *Knowledge is remade in each meeting:* The first point highlighted by the ESRs reflects the "becoming energy experts". On it, they see collaborations as a way to understand the transition from "several perspectives" and "build bridges between different fields". Thus, scholars willing to engage in collaborative practices are aware that each meeting, encounter and engagement is an opportunity for a new becoming (Barad, 2007)
- *Role of social interactions:* The second learning outcome derives from the role social interactions have on the research communities (Lemke, 2001). Communities serve as tools to make sense of the world. The ESRs recognize that collaboration "enhances open-mindedness", "helps to review research approaches", "adjusts research focus", and is beneficial for learning how to communicate results to diverse audiences.
- *Planning and preparation:* The third outcome is related to how to deal with the challenges that emerge out of the practices of collaboration. ESRs mentioned in the questionnaires the need for organizational planning and pointed out the need

for a “coherent strategy to obtain expected results”. Once a coherent strategy is provided, and the exchange of perspectives from disciplinary fields emerges, ESRs must have an awareness of the “limitations of one´s understanding in other related disciplinary fields” and that when collaborating, experts simultaneously take the role of “beginners and experts”. Thus clarification about basic concepts can be necessary and common.

In the next section, I have summarized a framework we developed with colleagues based on a diffraction reading from crossing disciplinary boundaries.

4.4. INTERDISCIPLINARY ENERGY RESEARCH FRAMEWORK BASED ON POSTHUMANISM AS BOUNDARY-CROSSING

Based on the article:

> **Godoy, J.,** Otrel-Cass, K., Gorroño-Albizu, L., and Yang, J. (2022). **Reflection through Diffraction: Interdisciplinarity in Energy Science**, Knowledge Cultures 10(2): 95–122.

As expressed in the abstract, the article's approach and findings are the following:

> “To address the complexities associated with transitioning towards sustainable energy solutions, there are increasing demands to employ interdisciplinary approaches. However, these still represent a minority of research projects. This is due to the well-known understanding that researchers’ skills and methods are largely anchored within their nested disciplines, and to be working in an interdisciplinary manner would require reading and understanding each other’s disciplinary ‘language’ in order to consider how different fields can work together towards joint solutions. This article presents a structured approach by early career researchers to learn about different disciplines’ epistemological and ontological assumptions through the material engagement of each other disciplines. It includes a joint production of an annotated bibliography, followed by a cogenerative dialogue to unpack each other’s knowledge acquired in practice through agency and not merely observation. Theoretically, the approach is underpinned by

> theories proposed, amongst others, by Karen Barad, who advocates diffractive readings of each other's fields to explore the relations between the social and the scientific."
>
> Godoy et al. (2022: abstract)

The results reported in section 4.3 holistically revealed the performed practices of collaboration in the ENSYSTRA project. In this section, I discuss the practices of interdisciplinary research carried out in my work package (WP3: Actors behaviour and interactions). As presented in the abstract above, together with my team, we proposed a framework for approaching interdisciplinary energy research. The framework considers disciplinary boundaries as habitues. Thus, scholars need to learn to understand each other's epistemological and ontological cultures. The framework aims to advance such understanding based on three main steps: production of a joint annotated bibliography, performing a co-generative dialogue, and reflection on boundaries crossing based on a diffraction reading. Based on the theoretical insights of habitus and diffraction, this practical approach allowed us to cross the boundaries between WP3 ESRs, building bridges between disciplinary fields. The following key steps were taken:

- *Understanding each other disciplinary backgrounds:* Communication challenges can hamper the construction of interdisciplinary research outcomes (Cohen et al., 2021; Spaapen et al., 2020). As a first step to overcoming the challenges of communication between experts in different fields, we adopted a strategy of building a common vocabulary. For this, we built an annotated bibliography (available in Godoy et al., 2020), where each scholar was responsible for highlighting the most important references and outcomes for their research development. Such an approach allowed to "share significant representatives and thinkers", translate relevant insights from one´s domain and develop a common ground of understanding (Godoy et al., 2022, p. 103).
- *Cogenerative dialogue:* After reading and understanding each other´s disciplinary ´language´, we discussed the literature following the cogenerative dialogue methodology (Roth & Tobin, 2001). Discussing the insights from the

literature was a way of understanding the authors' lessons together and building a common understanding from there. Recording the discussion, transcribing, and reflecting on the cogenerated dialogue was a way of being conscious of one´s discipline limitations, as well as the opportunities for crossing boundaries and the intersections between each other fields.

- *Diffractive reading:* method considered to provide alternative modes of qualitative inquiry (Mazzei, 2014) and train us to more subtle visions (Haraway, 1992). To Karen Barad (2007), diffractive methodology "provide a transdisciplinary approach that remains rigorously attentive to important details of specialized arguments within a given field, in an effort to foster constructive engagements across (and a reworking of) disciplinary boundaries" (p. 25). Thus, the insights that the diffractive methodology provided allowed to look at different areas of study in energy research with a focus on "actors behaviour and interactions". In addition, the approach favoured being attentive to specificities of disciplines' relationships, differences, and significations.

Research questions the article answered:

- How can we orchestrate the conditions that assist us in thinking and learning together about our differences and situate one's knowledge in an energy transition research project while producing new insights?
- How can we practically facilitate a 'direct material engagement' to exchange ideas on how to examine the 'world'?

Main findings of the approach:

- Diffractive reading allowed to expand the ideas from the literature review and commonly built new research directions and inquiries.
- The adopted approach of direct engagement with disciplinary materials, followed by a group reflection and reflective analysis of the transcript, demonstrates that scholars could visualize new inquiries and solutions based on application-driven knowledge, a characteristic of interdisciplinary research (Van Rijnsoever & Hessels, 2011).

- Since interdisciplinarity is also about practices that are in conversation with one another, the diffraction analogy and methodology allow understanding the effects of one field on another in the practices of knowledge building (Barad, 2007).

The next section presents insights acquired from an insider scholar in interdisciplinary energy research.

4.5. AN INSIDER PERSPECTIVE ON INTERDISCIPLINARITY

In the directions that interdisciplinary encounters on the ENSYSTRA project took, I questioned myself about the knowledge being generated, the inquiries being made, and the research questions being answered. Are those reflecting the energy experts' concerns and their perceptions of the solutions for the climate crisis? Or are those driven mostly by disciplinary traditions and the habitus of the niche those scholars belong to? Almost half of the ESRs in the ESNYSTRA project come from the global south, where most of the effects of the crisis are lived and felt. It seems likely that most of those ESRs have lived and experienced the impact of a lack of justice, ethics and responsibility for the climate crisis. However, it also seems likely that a disciplinary shaping of engineering courses is influencing the direction of research enquires towards technoscientific thinking, where questions of energy justice, inequalities, and responsibility are barely integrated into research inquires. Equity and ethics are recognized as fundamental for addressing social issues, e.g. reducing vulnerability and eradicating poverty (IPCC, 2018, p. 84). However, it is unlikely that those issues become central in energy systems resulting from the transition if those issues are not being at the core of the research inquiries since the beginning of the process. Gilbert Hottois (1987) sees that technoscientific practices are often driven by technopolitical decisions that intersect matters of ethics and engineering, but as the link is so complex and of long-term effect, it is equally complex to see the consequences in the short term. Considering energy transitions as inseparable ethico-onto-epistemological matters, as proposed by Karen Barad (2007), provide research approaches where ethical inquires on energy systems are entangle with the practices of the present. Next section summarizes the chapter findings.

4.6. SUMMARY OF THE CHAPTER: (INTER) DISCIPLINARITY

The purpose of this chapter was to explore the interdisciplinary practices in energy research. Developed upon collaboration between ESRs of the ENSYSTRA project. Insights on the characteristics of research outcomes, motivations, challenges and learning outcomes were analysed based on material-discursive perspectives. See main contributions in Table 6.

Table 6. Characteristics of the collaboration practices of ESRs in the ENSYSTRA project.

Characteristic	**Main arguments**
Research Outcomes	• Collaboration in the ENSYSTRA was driven by mandatory outcomes, where researchers adopted pragmatic approaches to research • Since collaboration is impulsed by social practices, providing encounters is the key to interdisciplinary practices to happen. • Interdisciplinary, international, and cross-sectoral purposes are linked to the instrumental role of science. • Energy transition as a socio-technical problem needs interdisciplinary development. However, in projects with the main focus on technical areas, social science becomes a mere background for technological developments.
Motivations	• Visionary expert perspective: where the ESRs believe experts must have holistic views of the energy transition. • Disciplinary habitus: learning is motivated by the objective of reinforcing disciplinary knowledge.
Bottlenecks	• Disciplinary lock-in: disciplinary habitues works as a mechanism of disciplinary lock-in.

	• Institutional habitus: institutional traditions reinforce conventional structures that incentivize disciplinary research outcomes.
Learning outcomes	• Knowledge is remade in each meeting: each encounter incentivizes the formation of new perspectives. • Social interaction role: scholars advanced research inquires, discussions and clarifications of jargon from disciplinary backgrounds are embodied processes. • Planning and preparation: due to the complexity of collaborating, structured approaches for interdisciplinary collaboration tend to result in better outcomes.

Structured approaches can facilitate interdisciplinary collaboration. Based on that, a framework was developed to help scholars in this process. The framework was based on a diffractive reading. See the main characteristics in the following table.

Process	**Argument**
Theoretical background: Diffractive reading	Allows highlighting the insights that one discipline generates into another. Finding the patterns of differences.
Methodological approach: Annotated bibliography followed by a co-generative dialogue	Share significant representations of disciplinary fields and integrate key insights. Discuss and explore disciplinary and methodological limitations.
Diffractive encounters	Highlight field differences. Build interdisciplinary knowledge. Produce an integrated perspective on energy research.

	Disciplinary fields leave a mark on each other (agential cuts).
Learning outcomes	Generate new inquiries for the research problems. Identify gaps in disciplinary approaches were identified.

In the next chapter, I explore the energy experts´ perception of the environment to understand the underlying assumptions supporting the dualism of nature-culture, humans-nonhumans, subjective-objective knowledge (discussed in section 2.1) and how those core ideas drive sustainable energy transitions.

CHAPTER 5. PERCEPTIONS OF THE ENVIRONMENT

Through an exploration of global and local narratives, this chapter proposes methods and narratives on human-environment-nature relations required to address the climate crisis. I begin by synthesizing the critical challenges of the Anthropocene for nowadays geopolitics, such as the need to find equilibrium between global decisions and local actions. Global challenges and the local environment set the context for the energy experts in the North Sea Region and shape their perceptions. Then, I present theoretical justifications for the impact of energy experts' perceptions on developing sustainable energy transitions. Finally, I present global and local contexts that influence energy experts' decisions to a greater or lesser extent.

This is set against the backdrop that the authors of the IPCC report highlight the need to deliberate local energy experts' narratives, mainly because local responses are required to strengthen and implement global responses. Although current global responses may indicate possible actions that can reduce the emissions required for maintaining the temperature below 1.5°C, the confidence is lower at a local level (IPCC, 2018). Hence, the involvement of regions, cities, communities, and businesses in actions that increase local actions is fundamental for closing this gap. Furthermore, such an involvement necessitates enhancing institutions' ability to apply indigenous and local knowledge in all countries (IPCC, 2018).

By exploring global and local narratives on the climate crisis, as well as the influence of energy experts´ perceptions driving local actions, this chapter contributes by:

1. Reflecting on the Anthropocene narrative and influence of the perceptions of human beings in driving behaviour, as well as on the challenges that climate crisis´ perceptions bring to geopolitics and areas that require further investigation and the development of practical actions (inspired by the views of Bruno Latour (2018)). Contributes to answering the specific research question number one.

2. Examining the underlying dichotomies and dualisms between environment-nature, nature-culture, humans-nonhumans, subjective-objective knowledge, and the implications of such dichotomies for the transformation of energy systems. Contributes to answering the specific research question number two.
3. Investigating energy experts´ perceptions of their local environment, as well as the primary drivers of those perceptions in the context of the North Sea Region. I present a case study built upon energy experts' experiences from a company that produces and provides electricity. Contributes to answering the main research question of the thesis.
4. Discussing local knowledge and Scandinavian local perspectives on the management of energy resources and actions undergoing the energy transition. Contributes to answering the specific research question number one.

This chapter is based on my article on the "*Energy transition innovators´ perceptions of the environment*" (in preparation) and my review of Bruno Latour´s book "*Down to Earth: Politics in the New Climatic Regime*" (Godoy, 2020). My theoretical analyses are mainly influenced by the theories of the Norwegian philosopher Arne Næss, the contemporary British philosopher Tim Ingold, and the French philosophers Bruno Latour and Pierre Bourdieu. While conducting this research, I stepped into the context of humans-Earth relations with the anthropogenic climate change introduced in section 1.2.1 and deepened by posthumanism theories, as explained in section 2.1. In the next section, I extend those discussions by theoretically investigating the lessons we can learn from the Anthropocene narrative about human-Earth relations.

5.1. LESSONS FROM THE ANTHROPOCENE NARRATIVE

To write about the Anthropocene means to consider the geological history that is defined by humans´ influence on their surroundings (Crutzen, 2021). Paul Crutzen's used the term Anthropocene in a speech to emphasise and link the term to his concerns about human-Earth relations (Crutzen, 2021; Zalasiewicz et al., 2017). There is an ongoing debate over adopting the Anthropocene term for the current geologic era,

which stems from the realization of humans´ dominance of their environment and raises questions over their power and ability to shape their future. Experts believe that the Anthropocene began in 1950 (see details on Zalasiewicz et al., (2017)), whereas, in the IPCC report, it is considered that the Anthropocene might have onset in the mid-20th century. Further considerations on the Anthropocene reflect that it should account for geological merit and follows the Holocene as a formal epoch in the Geological Time Scale (IPCC, 2018). Here, using Anthropocene as the term for a geological epoch is critical since it can provide insights into the past, present, and future of humans' relationship with the environment (IPCC, 2018). This chapter is in line with the sentiment expressed through the term Anthropocene because it investigates energy experts´ (humans) interactions (or, more accurately, intra-actions) with the Earth Systems. Understanding the drivers, dynamics and challenges of human-environment interactions has implications for how we manage the environment (Autin, 2016).

Meanwhile, anthropologists' concern is on discussing the narratives awakening with the popularization of the term "Anthropocene". To Donna Haraway, understanding Anthropocene as only a human species act and disregarding the "highly complex systematicity of situated peoples and their apparatuses, including their agricultural critters and other critters" is a mistake (Haraway et al., 2016, p. 539). Similarly, Karen Barad (2007) believes that human-environment relations, such as the ones influencing the geological era, are a result of the mutual constitution of those entities via intra-actions instead of interactions. Such a standpoint allows reflecting on how experts perceive the environment and their influence on unfolding energy transition projects. It also allows the understanding of how experts´ perceptions are influenced by historical settings, events in their surroundings, and the landscape and culture in which they are immersed. Tim Ingold (2002), like Karen Barad and Donna Harraway, believes that humans and things do not exist as delimited entities nor are external to their surroundings. Instead, they are a continuous unfolding of relations. He contends that "people and their environments are continually bringing each other into being" as part of the same world that is both social and natural (Ingold, 2002, p. 87).

Tim Ingold's ecocentric proposal is that instead of considering the plants and animals as part of the humans´ environment, we could consider humans and our activities part of the plants' and other species' environment (Ingold, 2002). I wonder, how do our perceptions of responsibility change when adopting such a standpoint? Will we feel a more moral responsibility to contribute to our core "institution" (ecosystem) and thus be able to keep developing human activities? Also, will we continue to see nature solely in terms of its potential capital, exploiting the resources as if they were there to serve human needs?

The ethical questions related to the Anthropocentric mindset present in the Western societies´ understanding of human-environment-nature relations has at its core the instrumental role of economic exploration of resources. Sian Sullivan´s (2014) concept of "natural capital" investigates how the values of, e.g. stock of forests, minerals, land and nonhuman natures are the underlying structure of green economies. These resources and nonhuman natures are transformed into assets of a new market economy (for example, carbon markets) (p. 1). However, those green economies are virtual green economies based not on an economy focused on the production of goods but instead on the absence of materials (Bracking, 2015). Virtual green economies are being leveraged through performative narratives, discourses, actors, institutions, and technologies, which can in fact, create a fictitious economy (Bracking, 2015). As Larry Lohmann (2016) analysed, the value of virtual economies is on social relations, since in this form of capitalism, the acquisition of emissions credit allows companies to be labelled as not polluting (even when they are discharging chemicals into the environment) (in Bracking, 2015)). Do such models give the right to keep polluting, guilty free? What are the ethical paradigms of a physical location being treated as having an instrumental value while the fictitious economy as having an intrinsic value? How is a virtual economy based on social connections and networks favouring a world made of a "brotherhood of man[27]"? Questioning the solutions being proposed for the Anthropocene with ethical perspectives allows to visualize such problematics.

[27] Reference to the "What´s up?" song written by Linda Perry and performed by the 4 Non Blondes band. Where she expresses a feeling of exhaustion towards cultural characteristics of

Similarly, for fruitful debates, we can consider the use of the Anthropocene term to be a “boundary object” that can adapt to different perspectives while maintaining the identity of viewpoints (Star & Griesemer, 1989, p. 387). Thus, this term is relevant for enhancing the collaboration across disciplines and contributes to emphasizing disciplinary limitations, epistemological tensions and narratives needing replacement (Brondizio et al., 2016, p. 321). Furthermore, the term allows for building holistic perspectives by bridging knowledge from several sources and integrating dimensions that favour the views toward minimizing global problems (Brondizio et al., 2016). Such insights are required to visualize contemporary problems and those related to how we perceive energy in society, developing strategies for re-designing energy systems.

What is missing, however, is translating such knowledge into practices of energy experts in order to change society's reality imbued in structures and maintained by our habitus (Bourdieu, 1977). Thus, a primary concern is the need to situate energy experts' understanding of their environment and their role in deepening societies' relation to our environments. As Latour wrote, the biggest challenge for humans with climate change, and all associated problems, is that we need to rediscover what it means to be human (Godoy, 2020; Latour, 2018). Such a call is deeply connected with the need for a perspective shift on how we perceive ourselves, going beyond traditional dichotomies (humans-non-humans, culture-nature). This implies going beyond human-centeredness views that position human beings at the top of a hierarchicy in relation to other non-human matters. Anthropocentric systems position non-human matters, such as nature and natural resources, for the benefit of man. Encouraging the belief that the value of non-humans is merely instrumental for human needs.

In the next section, based on the insights built upon the review of Bruno Latours´ book: Down to Earth: Politics in the New Climatic Regime (Appendix C), I discuss the nature-environment-society relations the consequences of dichotomies between those and lessons for political decisions.

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society and institutions, calling “for a revolution”. The song was in the top charts in countries like Germany and Denmark, which can be a reflection of shared feeling.

5.2. ANTHROPOCENE LESSONS FOR GEOPOLITICS

Based on the article

> **Godoy, J.,** October 2020 **Book Review: Down to Earth: Politics in the New Climatic Regime.** *Front. Clim.* 2:524365. doi: 10.3389/fclim.2020.524365

The article reviews the narrative presented in the book Down to Earth: Politics in the New Climatic Regime by Bruno Latour (2018). Latour´s in-depth reflection on the interrelationship of human behaviour, societal problems, and the climate crisis helps to navigate energy experts' possible feelings and origins of perceptions. Furthermore, the insights provided critical theoretical support for comprehending the complexities and responsibilities of energy experts in restructuring societal relationships with energy resources and nature. Thus, those reflections can help in aligning and balancing the narratives to generate deep transitions. The main messages my review synthesizes from Bruno Latour´s book (2018), which are relevant to incorporate into the practices of energy experts, are:

- *Inviting to a nature-as-an-actor perspective:* by recognizing nature as having its own agency, Latour intends to point out the need to live a synergistic relationship with nature. Nature has the ability to act and respond to human actions. Because, to him, nature must be treated as an actor, even if nature is a non-human or more-than-human[28] actor. Having agency, the way humans interact with nature determines society's equilibrium.
- *Going beyond dichotomies of the local and the global:* climate crisis deniers, according to his formulation, are linked to society´s attachment to a dwelling place (local) and the sense of modernization (global). However, with the signature of the Paris Agreement, society´s behaviour has changed due to inconsistencies (limited resources to maintain the globalization plan) and

[28] Non-human terminology comes from the Actor-Network Theory, which intends to extend the word actor to non-human and non-individual entities. ANT rebuilds social theory by including actants into the analysis of what is social, avoiding to falling into anthropocentrism and sociocentrism recurrent of social sciences understanding of society (Latour, 1996).

idealistic ideas of globalization, where he sees two emergent phenomena: *globalization plus*, that will mean adopting multiple views, but paradoxically it is the opposite in practice, adopting a single vision that represents a small number of interests, described as *globalization minus*.

- *Redefining an outdated definition of nature:* the definition of nature should not disregard nature´s agency. People that advocate for modernization (often associated with globalization) defend a system of production where nature is merely a resource. People still with such views do not have a sense of shareable living space, consequently disregarding the need for human-nature´s equilibrium.
- *Presenting an out-of-this-world culture:* aligned with the idea of the absence of an understanding of a planet shared by all, Latour coins the concept of *out-of-this-world* to define the attitude of climate crisis deniers. Often obscurist elites occurred with the realization of the consequences of human activities and that the earth is reaching its limits, summed up to the reactions of nature (as an agent). The result is a growth of nationalism, populism and migration.
- *Proposing new narratives and methods for sustainable transitions:* He proposes that we search for a shared world, a common orientation turning towards what he calls the "Terrestrial" (Earth we live on). Therefore, there is a need to redefine the concepts of globalization, localization, society, nature, and even what it means to be human.

The book reflects on the importance of rethinking the core ideas on societies that led to the climate crisis, acknowledging Europe´s responsibility over the crisis. Furthermore, Bruno Latour´s (2018) book allocates the responsibility to take society through this process of rethinking our deep values as a duty of politics, highlighting that Europe is the continent more ready to lead this task. However, it is important to recall Rosi Braidotti´s (2013) critique of Europeans' behaviour of positioning themselves as the moral guardians of the world and the drivers of development. Europe's leadership in defining geopolitical affairs must recognize its responsibility

for the climate crisis and be done with empathy for the places that mostly suffer the consequences. Building on these insights, I discuss in the next section some considerations for further work.

5.2.1. REFLECTION ON GEOPOLITICS[29]

Geopolitics on climate change, presented in Bruno Latour's book, will benefit if fundamentally different political regulations are proposed, mainly regarding the politics of nature. World Trade Organizations (WTO) rules strive to cover social, political and economic aspects related to trading between countries with the landscape of globalization and local capabilities. However, when it comes to our relationship with the environment and natural resources, the guidelines are limited to environmental risk (like the cascading risk of extreme weather events or effects of increasing deforestation) (WTO, 2021). Philosophies such as those proposed by Bruno Latour´s book can have applied contributions if practical guidelines are proposed. For this, further investigation can be done in regard to:

- *Trade unions between countries:* currently, countries can prohibit the import of goods from a country based on a product being dangerous for the nature or health of people in the producing/exporting country. But the prohibition of imports does not take place if a product is destroying nature and biodiversity and considering human conditions in the exporting country.
- *Emissions costs:* those related to long-distance trade having to pay for their emissions costs.
- *Trading of emissions:* Regulations based on the existence of a global world and space shared by all will fail to capture local degradation impacts. Failing to address questions of justice, inequalities and historical emissions debt.

Such insights and discussions with senior experts of the ENSYSTRA project were fundamental to aligning my research direction about the relevance of our perceptions

[29] Personal communications with Frede Hvelplund (senior expert in the ENSYSTRA) via e-mail generated the insights from this reflection, Jaqueline de Godoy, October, 29, 2020.

of the climate change problematic at global (economics-nature) and local (our surroundings) levels. See in the next section the role of our perceptions of the environment and how investigating this deeply can change the direction of how we use the resources.

5.3. ROLE OF THE PERCEPTION OF THE ENVIRONMENT

Our reflective abilities towards our practices and habits require, firstly, an understanding of our perceptions of the world around us. The manifestations of Tim Ingold (2002), in his book *The perceptions of the environment*, dive deeply into misconceptions on societal perceptions about human-environment-nature relations. Those matters belong to the fields of philosophy of ecology, environmental ethics and deep ecology or ecosophy (e.g. Næss, 2009), which aim to develop theoretical formulations about humans and their environmental spheres. Arne Næss (2009) book Ecology of Wisdom understands the word ecosophy as composed of ecology (study of interrelationship) plus sophia (wisdom). Thus, the deep ecology movement which emerges in the Scandinavia stands as a philosophy of ecological harmony or equilibrium. Arne Næss (2009) was inspired by Gandhi´s analysis of self-realization, and it intends to contribute towards non-violent actions, which can be achieved by living deeply in commitment to our home place (section 5.5 summarizes the article C where I explored the energy experts' perceptions of the environment and of the needs of the community they serve). Applying knowledge from those fields favours restructuring human societal values, our practices relating to environmental degradation and the construction of pathways to harmonious life between species (including our own specie). Those authors call for a new way of thinking about organisms and their relations with their environments: “a new ecology” (Ingold, 2002 p. 173). I wonder how in this context, humans-environment-nature matters are understood by the energy experts? And how can their knowledge drive energy matters towards just energy futures?

Broadly speaking, energy experts' ability to conduct energy systems aligned with harmonious ways of living depends on their perceptual skills. Tim Ingold (2002) argues that perceptions are not just formed in the mind but also as a process of the

sensorial body. To him, understanding through the mind or through the body are two ways of describing the same process, which is the "environmentally situated activity of the human organism-person" (Ingold, 2002, p. 171). Understanding perceptions as a sensorial process instead of representations mediated by the mind is aligned with the critiques (done by scholars like Gibson, Marleau-Ponty, and Heidegger) to the Cartesian dualism of mind-body, defended by René Descartes. The major contributions of Tim Ingold (2002) are in exploring how dwelling in the world shapes our sensory perceptions, where the mind and body play the role of sensory tools. Thus, the environment, that is, the world people inhabit, contributes significantly to our perceptions. To him, the environment shapes society as a continuous process, not as a predetermined one. However, although values, beliefs and practices can be characteristics predetermined by individuals and groups (e.g. energy cultures), they interactively influence systems and societies. Consequently, we can assume that energy experts´ perceptual skills continuously drive energy systems.

Energy-environment-society matters are the focus of the activities of energy expers and they drive sustainable energy transition. But, how is the environment perceived by experts? How are perceptions formulated and acquired? "Perceptions" can be compared to intuitive knowledge (Ingold, 2002), even though western traditions are sceptical about intuition as a form of knowledge. Intuition in sciences, for example, is seen as an inferior form of knowledge compared to other forms of knowing (Ingold, 2002). However, they are not configured in the domain of instincts instead of reason and abstract reasoning. Instead, intuitions rely on sensitive and perceptual skills (Ingold, 2002). Thus, intuitive knowing is fundamental for energy experts or scientists since they need a capacity for judgement which is built by their environment situatedness and discernment sensibility (Ingold, 2002). Furthermore, intuition can be seen as a "necessary grounding for any system of science or ethics that would treat the environment as an object of its concern" (Ingold, 2002 p. 25). As Yi-Fu Tuan (1977) discusses, our experiential senses are composed of feelings and thoughts. Both are sensory acquired and compose our know-how through life. Perceptions are connected to the relational context of people´s experiences of being in the world. To Tim Ingold (2002) "a place owes its character to the experiences it affords to those

who spend time there [...] and these depend on the kinds of activities in which its inhabitants engage" (Ingold, 2002 p. 192). Places have their unique significance (incorporated historically) and contributes to how we experience the environment.

The environment shapes peoples' perceptions. But, how is culture related to the way we interact with our environment and other species inhabiting it? Culture can be seen as a mediator between people and their environment (Ingold, 2002). And as a fundamental entity to define nature (Latour, 2017). However, when it comes to understanding culture and nature relations, the Western conceptualization sees nature and culture as separate entities (Pollini, 2013). In Bruno Latour´s (2017) book Facing Gaia: Eight Lectures on the New Climate Regime, the understanding of nature and culture as opposed to each other was named as *Old Regime*, proposing the current era as the *New Climatic Regime*. New climatic regimes redefine the understanding of the relationship between nature and culture since they cannot be separated from one another. Latour sees that humans cannot avoid the constraints of nature. Thus, to define nature, we need to define culture (Latour, 2017).

Humans cannot escape the constraints of nature. Thus, nature should not be understood as culturally constructed (Ingold, 2002). Understanding nature independent of culture generates a distributional agency (Latour, 2017 p. 99), where humans act in relation to culture, and the material things in the world (nature and objects) are defined by mechanical laws (Leahy, 2020). Neither should nature and culture be understood as opposite poles, such as the divide nature-culture. Understanding culture as the contrasting domain of nature fails to capture the depth of environmental problems (Murphy, 2004). Humans perceiving nature as an actor, instead of an outcome of a human agency like cultural constructs, clarify greatly how humans' natural laws and human agency contribute as hybrid spaces to shape real-world objects (Pollini, 2013). This favours the perceptions of specificities on how the world comes together. Favouring the reflection on the impact that humans have over nature (and the other way around) and on how far human-centeredness can impact when other species´ rights are disregarded in favour of prioritizing human needs.

Energy experts' perceptions rooted in dichotomies such as those of nature/culture and nature/environment influence the changes in energy systems. Tim Ingold argues that terms like society, nature, and technology are far from mere labels. They contain moral, political, and evaluative commitment. See next how the perceptions of the environment we inhabit drive energy experts' decision-making and ethical instances.

5.4. ENERGY EXPERTS' PERCEPTIONS MOLDING THEIR PERFORMANCES

The field of environmental ethics connects deep ecology to sustainable policies aimed at addressing contemporary environmental problems. Environmental ethics embraces questions of the moral relationships of human beings and our relationships with non-humans. However, contemporary knowledge produced by deep ecology movements on matters of environment-nature-culture is still unapplied or unknown in many fields, it remains disconnected from the practices of many experts working in energy research. The challenge of integrating such insights into the energy systems is partially linked to the sectorization between subjective/objective knowledge production and institutions rooted in disciplinary thinking (explored in chapter 4). But it is also greatly due to our perceptions of nature, culture, and environment, which often are seen as external to humans.

However, as observed by Arne Næss (2009), many people and groups seek to find a way to live a harmonious and richer life, which brings a great opportunity to diversify the perceptions of energy experts about energy matters in society. Energy experts, informed by the dichotomies of nature/culture and environment/nature, can have normative ideas where resources are there to serve human needs, driving their practices in relation to energy production and provision in society. But,

> *"for Barad there is no essentiality to what it means to be human either from the side of agency ("humans are emergent phenomena like all other systems") or in terms of being necessary for the presence of meaning. In fact, there is no privileged status given to humans at all"* (Dolling, 2009).

Analysis of energy experts' performativities and material-discursive practices can reveal their self-perceptions in relation to the environment they are immersed in, and

their influential ideas on energy systems. Making an analogy with Judith Butler´s (2010) ideas on economic markets, the directions of energy systems are far from being an existing and autonomous reality since the repetition of performative practices constitutes them. Energy experts' performances can be called into question because systems are created by a set of discursive and non-discursive practices in institutions. Thus, being reflective on the core thoughts and narratives associated with energy systems reveals experts´ proposals for society´s lifestyle and the link of their practices with the future of energy systems.

Since we can question the normativity of energy systems by questioning energy experts' performances, and discursive and non-discursive practices, as a starting point, how can we define what solution is a better contribution to the decarbonization than another? For instance, on which assumptions of the environment, nature and society are the experts judging their innovations and future-making of energy systems? Standing on the understanding of performativity, Karen Barad and Judith Butler's theories allow challenging the metaphysical narratives of culturally constructed societies and understanding the several mechanisms that contribute to systems constructions (Butler, 2010). Studying energy experts' challenges and narratives when it comes to the task of intermediating changes in the environment is the key to efficient actions that decarbonize the NSR.

The complexity of the task for energy experts entails visualizing sustainable futures and taking actions according to those imaginary futures. However, sometimes the actions can at first appear to be counter-intuitive. This is because actions are based on concepts of the present and those become embedded in future systems (Oomen et al., 2021). Future carries the past, but also how the future is evoked shape or present (Skjølsvold, 2014). One example of this is the performance logic of numerical projections, recurrent in the IPCC report, where the future is extrapolated based on the present data (Oomen et al., 2021). The energy culture reinforces the practices of energy experts. As maybe Karen Barad (2007) would say, those energy cultures are an act in themselves. The implication is that when communities talk through, there is an enacting that has a performative effect and drives actions:

> *"It is not only the explicit speech act that exercises performative power; other exercises include (a) the mundane and repeated acts of delimitation that seek to maintain a separation among economic, social and political spheres, (b) modes of prediction and anticipation that constitute part of economic activity itself, and (c) organizations of human and non-human networks, including technology, that enter into specific economic activities such as price-setting (Butler, 2010 p. 150)".*

As Ulrich Beck (2008) argues, the politics required for climate change is cosmopolitan because, firstly, we are trapped all together in a problem that threatens our present and future. Secondly, single actions, like those of countries spending billions on single measures to protect their territory from the rising sea level, will not suffice to address the consequences of climate change. In the following section, I summarise the results of my study of energy experts at a local level.

5.5. PERCEPTION OF THE ENVIRONMENT AND ENERGY TRANSITION: SUMMARY OF THE ARTICLE C

Based on the article

> **Godoy, J**. (2022) (To be submitted) Energy transition innovators' perception of the environment.

Preliminarily insights of the article can be seen in the abstract:

> "The environment, that is, the world people and all living things inhabit, is a continuous shaping by all the activities of living beings that inhabit it. Understanding how people perceive their environment is critical since this perception may influence their actions towards sustainable energy transitions and, consequently, the environment itself. In this article, I present an analysis of the perception of the environment that experts of a Norwegian energy company have. I explored how energy experts' environment, culture, and experiences shape their beliefs. These experts are tasked to come up with

> innovative solutions for the energy sector and respond to the challenges presented by climate change. Methodologically, ethnographic methods and semi-structured interviews were carried out. Thematic analysis of these experts´ narratives shows that their perceptions of the environment are influenced on the one hand by how they define the environment and their engagement with it, as well as by their perceptions of the natural resources, the community needs and the climate crisis. On the other hand, by their life histories and the materials with which they engage daily."
> (Godoy, 2022, abstract, article in preparation)

In the article, I explored the perceptions of the energy experts from a provided and producer energy company in Scandinavia. The region where the experts work strongly connects with renewable energy resources. The influence of energy on that region is on the basis of economic development, the imaginary collective of people and on how energy infrastructures have shaped the landscape through the years. The meaning of energy at the local level greatly influences countries' energy cultures (Stephenson et al., 2021)). Similarly, the dynamics of national culture are influenced by the decisions of energy experts and their energy cultures, which consists of the interplay between normative, material, institutional and policy factors. Thus, those energy experts have a decisive role when it comes to shaping energy systems of the future. They are tasked with serving the community, providing jobs from the sector, guaranteeing societal development and provisioning energy. Besides, creating actions adequate to the community's wishes and needs. Furthermore, as national culture is also potentially influenced by supra-national influences, such as decisions of the World Trade Organization (WTO) and the EU (Stephenson et al., 2021), they need to act in accordance with geopolitical agreements. The energy experts are guided by geopolitical affairs, as well as by global market tendencies (such as the propagation of business models based on big data analytics) and for strong local energy cultures and moral responsibility towards the community they serve. All of those influences were seen in what the energy experts perceived about their environment, the natural

environment that surrounds them and the culture they influence and are influenced by. The case-study show how energy experts perceptions influence the decisions on energy systems. The main research questions that guided the article were:

- *How do members of a Norwegian energy company perceive their environment? How are these perceptions articulated?*
- *How do the perceptions of their environment influence the thinking and/or practices of the members of an energy organisation?*
- *What other factors (humans and non-humans, material-discursive practices, actors, life background and imaginaries) influence energy experts' perception of the environment?*

Methodologically, the article was a result of a three-months of ethnographic research. During the research stay, I took the role of an active participant in their company tasks, analysing internal documentation (such as blog posts) and documents from projects. Furthermore, semi-structured interviews lasting from 35 minutes to 2 hours were carried out. See below the summary of the main (preliminarily) findings.

- *Perceptions on the needs of the community:* energy experts see their role as responsible for the changes in the community. For instance, they have consciousness that changes on customers behaviour (social practices) are associated with providing information through the use of technology, empowering the consumers, avoiding misinformation and giving the trust back to the customers. However, the importance of implementing practices that deal with social factors and community exchange can be sometimes hampered by the other activities of those experts carry.
- *Imaginary futures:* the undergoing changes in energy systems pointed out by the energy experts influence the future of energy for society in three ways: In relation to the behaviour of the users, in relation to the environment and in terms of the structure of energy systems.

5.6. SUMMARY OF THE CHAPTER

- **Nature´s agency**: first, the agency of nature must be recognized in the narratives when discussing actions on sustainable energy transitions. Second, this implies acknowledging nature´s dynamics when studying environmental issues and when changing infrastructures of energy systems (Murphy, 2004). This means accounting for factors that go beyond socio-cultural analysis, such as those that regard "new instability of nature" (Latour, 2017 p. 35) and nature´s capacity to react to human interferences, consequently causing what we call natural disasters.
- **Sense of detachment from global problems:** How the polarization of people's behaviour reflecting on the geopolitics of the climate crisis problematic influence the perceptions of humans, and what actions need further investigation (inspired by the views of Bruno Latour (2018)).
- The research shows the importance of reflecting on the consequences of decisions on energy systems with the underlying dichotomies and dualisms between environment-nature, nature-culture, humans-nonhumans and subjective-objective knowledge.
- I explored the perceptions of energy experts' from a producer and provider energy company about their local environment and the primary driver of those perceptions in the context of the North Sea Region.

Next, I present part two of the results of this thesis. It focuses on comprehending the relationship between cultural aspects and socio-technical systems. The perceptions of energy experts are investigated with a focus on their perception of the processes on energy systems.

SECTION 2: Cultures on Socio-Technical Energy Systems

Socio-technical systems are formed by the mutual shaping of social and technical subsystems (Leonardi, 2012). Cultural aspects present in socio-technical configurations can shape energy experts´ perceptions, and their perceptions can drive the development of those systems. This section of the thesis demonstrates how cultural embeddedness and energy experts´ perceptions of the processes and the environment drive project developments in the energy transition.

In chapter 6, I investigate how local cultural trails influence the development of district heating (DH) systems. These systems are considered socio-technical configurations and natural monopolies. This can make it difficult to simultaneously achieve equitable institutional conditions and meet the needs of customers. Fortunately, considering the cultural characteristics when designing institutional conditions can favour fairer conditions for societies. The chapter explores the role of societal trust and the trustworthy behaviour of energy experts in the development of those systems. In turn, chapter 7 is situated in the global context in which digitalization and practices associated with big data are spreading to the energy sector. The chapter focuses specifically on big data analytics and surveillance capitalism practices. It shows how disciplinary research methods influence energy experts' perceptions, driving their practices, their research outcomes, their products and the sustainable energy solutions they propose. I also consider the impact of digitalisation practices on cultures of trust, such as those found in Scandinavia. Finally, I discuss the need for

ethical frameworks to guide the socio-technical developments while protecting customers' privacy rights.

CHAPTER 6. TRUST, POWER AND SOCIAL CAPITAL IN DISTRICT HEATING SYSTEMS

This chapter is the result of analysing the influence of socio-cultural aspects in socio-technical energy systems. Specifically, I focus on the energy experts´ perceptions about the processes in socio-technical systems and the influence of those perceptions on the strategies of organizations and institutions. The case explored here is that of the DH systems from Sweden and Denmark. Energy experts' perceptions greatly influence the design of institutional configurations that allow consumer power and the inclusion of principles of fairness and justice. Those factors, in turn, affect the trustworthiness of socio-technical systems, which enhances the development of environmental pro-projects, the cooperation of several actors, and enables changes in business models. This chapter also discusses the role of societal trust in developing those systems. Trust in Scandinavia is not a "silent tradition", maybe a complex one for documenting, but it is definitely a symbolic and cultural social capital of that region (Bourdieu, 1994).

As the theoretical background of this thesis evidenced the aim of adopting theories of posthumanism, I extend the analysis of DH systems by including insights on agential realism and analysing those energy systems as sociomaterialities. DH systems are considered sociomaterial and sociotechnical processes. Sociomaterial perspectives, in a nutshell, mean viewing phenomena as both material and social simultaneously (Leonardi, 2013). Similarly, socio-technical perspectives mean considering societal and technical factors as jointly shaping energy systems (Leonardi, 2012). This means analysing socio-technical systems as being mutually shaped by discourses, resources, technologies, society, materials, cultural characteristics, and policies, among others. Such a perspective has been fruitful in overcoming the dichotomies between society and technologies, subjectiveness and objectiveness, and nature and culture (Moss et al., 2016).

The following section broadens the analysis of DH as socio-technical systems, expanding the understanding of their development by bringing insights into their sociomaterial factors. DH systems are considered a representative sample of the socio-technical systems of relevance for this thesis. The choice of these systems as the object of study was due to the relevance that the heating sector has for decarbonizing the energy sector, their social value for societies of the NSR and the possibility of collaborating with one of my ENSYSTRA colleagues[30] in interdisciplinary research.

6.1. SOCIOMATERIALITY AND SOCIO-TECHNICAL ENERGY SYSTEMS

Since sociomaterial elements influence socio-technical systems, paying closer attention to them can reveal crucial factors for energy projects development. In order to understand socio-technical system directionality and the transitions that are emerging in the accelerating or stabilizing phases, it is necessary to research the many variables involved in specific niches (Schot & Kanger, 2018). Since deep transitions change core socio-technical characteristics, directing and influencing societies' lifestyles, it is crucial to map the factors enhancing the ongoing developments to decarbonise the energy sector, as well as to characterize which changes are taking place (Schot & Kanger, 2018). This chapter investigates sociomaterial factors that influence the development of socio-technical systems, specifically DH from Denmark and Sweden.

The transformations in energy systems are materializing as a consequence of several practices between entangled social and material elements (Hawkins et al., 2017). Karen Barad explains that sociomaterial processes are the entanglement of social and material factors and are not considered distinct or pre-existing entities (Barad, 2007). This differs from a Foucauldian account, where materiality analysis builds upon the concept of “dispositive”, which tends to mean the social reality that is given to the materials (Moss et al., 2016). The critique of this approach is that it does not consider

[30] Cooperation carried out with my colleague Leire Gorroño-Albizu from the ENSYSTRA project and the Department of Planning of Aalborg University. She was the responsible for introducing to me the link between trust and DH systems after my presentation on Scandinavian trust and digitalization during the ENSYSTRA meetings (chapter 7).

matter as an active factor in material-discursive processes (Moss et al., 2016). Following a Baradian agential realism argument, materialities do not result from human agency. Furthermore, she does not distinguish between discourses and matter. Thus, discourses are material (re)configurations of boundaries, properties and meaning, whereas material-discursive practices produce different sociomaterial configurations. An analysis of energy projects within this framework consists of looking at the material-discursive practices that generate the sociomaterialities, revealing insights into how, what, why and what is not materializing. In practice, this can facilitate tracing the elements and concerns that are not being addressed in socio-technical systems, the possibilities that are not on the imaginary collective of the energy experts and allowing an allocation of responsibility and discussing ethical aspects of what is and is being "excluded from mattering" (Barad, 2007 p. 187).

6.2. DISTRICT HEATING AS SOCIO-TECHNICAL SYSTEMS

The section above discussed the socio-technical systems and the relevance of studying them as sociomaterialities. In this section, I further explain the socio-technical characteristics of the DH systems studied in this chapter. Those systems are considered an important part of the energy transition since emissions from the energy sectors are the highest in the EU, and half of those are from the heating sector (European Commission, 2016). Furthermore, DHs are considered fundamental for decarbonising the energy sector since their technical characteristics could enhance sustainable energy systems. Among the benefits of DH, systems are that they promote the decentralization of energy systems, energy efficiency, and the integration of other technologies. Those systems distribute hot water to consumers by providing heat through pipeline distribution, heating citizens' homes. DH integration into target areas of urban infrastructures may offer advantages to decarbonising the heating and cooling sectors and the overall energy system (Brown et al., 2018; Connolly et al., 2014; Möller et al., 2019). The water in the pipelines can be heated from various energy sources, with waste heat being a common choice (Di & Ericsson, 2014). DH also enables using local energy resources that would otherwise be difficult to utilise, such as geothermal energy, waste heat from power plants and industry, biogas

production and solid biomass such as straw (Lund et al., 2010). Furthermore, DHs enable a higher integration of intermittent renewable resources (Gudmundsson et al., 2018; Lund et al., 2010). The benefits of DH are environmental sustainability, economic reasonability (in populated areas), and facilitation of the development and integration of other energy technologies. Such systems are found to have higher efficiency than individual heating and cooling alternatives(Lake et al., 2017).
However, the development and functioning of DH systems depend on social and technical factors. Thus, we studied and considered them as socio-technical configurations (Reda et al., 2021). DH systems are vertically integrated natural monopolies (Wissner, 2014), and the public is often concerned with the conditions they are offered to connect to those systems. For instance, in public debate, the effectiveness of regulation to guarantee fair heating prices and conditions is one of the ethical questions raised concerning DH systems in Sweden (Forsyningstilsynet, 2020). Several factors (e.g. price variation, mandatory connection) can make the customers tempted to opt for individual heating solutions. This is problematic since customer adoption and connectivity rate is fundamental for maintaining low prices, and a low connectivity rate can hamper the environmental benefits, stagnating DH development.

Our social scenario of analysis is based on Denmark and Sweden, two countries located in Northern Europe and belonging to the Scandinavia region. Both Denmark and Sweden have a welfare state model and an advanced mixed economy. Our interest in exploring DH systems in countries where its implementation is advanced was, first of all, to understand how those existent models could advance towards even more participation and control on the part of the customers. Second, to cross-culturally compare Sweden and Denmark to see the impact that specific cultural characteristics had on shaping socio-technical systems. Third, exposing the success cases of those countries could help other countries who wish to develop DH systems, as well as provide insights into developing other socio-technical systems.

6.3. ROLE AND PERCEPTIONS OF ENERGY EXPERTS

Understanding the energy experts' roles and responsibilities in sustainable energy transitions is complex. Some scholars argue that energy experts have influence as individuals (having agency) (Fischer & Newig, 2016). While other highlight that energy experts are part of organizations (system). Thus, their influential power is minimal (Fischer & Newig, 2016). However, changes in institutions are linked to the behaviour of energy experts when it comes to cultural-cognitive, normative and regulative aspects (Scott, 2013). At a local scale, we can consider that it is in the hands of energy experts to drive changes in energy systems, influence communities, and make decisions about regulations and institutions. Often their decisions are based on their perceptions, which can be supported by cultural or expert heuristics, e.g. experts' heuristics on households' energy use can influence decision-making, but their judgments can be inaccurate (Kantenbacher & Attari, 2021). Energy experts make decisions daily, and some of those have effects that will perpetuate for future generations. The complexity for the experts is that their decision-making on energy systems is partially associated with coordinating global problems of the climate crisis. This entails adjusting to national targets of reductions in emissions while designing systems appropriate for the local cultural characteristics.

Energy experts are also tasked with coordinating systems and the actions of various stakeholders with their diversity of motivations (Elkjær et al., 2021). See for example, an study on the participation of stakeholders in energy flexibility in DH systems (Ma et al. 2020). This means it is crucial to align the energy experts' values and motivations for the energy transition, mainly in natural monopolies such as the DH systems where the public's best interests must be taken into account. Controversies concerning how the public is perceived and participates in energy projects exist since, according to Lene Elkjær, Maja Horst and Sophie Nyborg (2021) , the public will always engage in the development of the projects based on the interest of the developers.

The ongoing transformations in energy systems are inducing towards re-negotiating the roles and responsibilities of the energy experts (Rohde & Hielscher, 2021). However, institutions can change their structures in contradictory ways (Rohde &

Hielscher, 2021). Also, resistance to changes or to accepting the most sustainable solutions may be encountered. In turn, the adoption or resistance to new technologies is influenced by how the technologies are perceived and associated with personal risk or benefits. DH systems adoption in Sweden is linked to the benefits of economic aspects, reliability, security of supply and even the influences such systems have on increasing the market value of residences (Mahapatra & Gustavsson, 2008).

The energy transition is provoking institutional changes in socio-technical systems and also socio-cultural changes in the systems they are embedded. When it comes to customers, citizens are now co-creators, having new roles as co-producers of electricity and actively influencing decision planning (Elkjær et al., 2021). This new structure on the roles of citizens is leading to the emergence of new business models, new responsibilities for the different stakeholders, and changes in the electricity grid, contributing to increasing the grid's resilience (Labanca, 2017).

Technology evolution and institutional co-evolution have a path- dependency that makes industrial economies locked into fossil fuel-based energy systems (Unruh, 2002). Those factors can generate lock-in effects, slowing the process of changing societal lifestyle and consumption patterns, technological development and learning process, or institutional configurations. Increasing political coordination (maybe also hierarchical structure) is important to avoid the system collapsing or stagnating due to, for example, lack of focus (Labanca, 2017). Equally relevant are transparency and open communication to implement changes in socio-technical systems.

In the next section, see the exploration of energy experts' perceptions about the institutional aspects of DH systems and about their cultural characteristics.

6.4. FAIR INSTITUTIONAL CONDITIONS FOR CUSTOMERS

Based on the article:

> Gorroño-Albizu, L., **Godoy, J**., October 2020. **Getting fair institutional conditions for district heating consumers: Insights from Denmark and Sweden.** *Energy, 237, 121615.*

The article´s abstract reflects on the approach adopted for understanding the fair institutional conditions of DH systems:

> "District heating is expected to play an important role in the EU for the implementation of a low carbon energy system with high shares of renewables. Empirical examples from several countries show that district heating companies can misuse their monopoly position, hampering district heating adoption. To address this issue, it is necessary to develop and implement institutional frameworks that promote fair conditions for consumers. However, it is still unclear how to do this. This article reviews the institutional conditions implemented in Denmark and Sweden from the start of district heating until the present and analyses why different institutional configurations have managed or failed to promote fair conditions for consumers. The analytical framework for consumer power in natural monopolies is applied. The data is collected via a structured literature review, interviews with experts and other data sources such as resolutions of consumer complaints, relevant stakeholders' websites and legal documents. The results indicate that local ownership, transparency and communication have been of key importance to reduce prices in both countries. Further research is necessary to fully understand how the institutional conditions have influenced product and customer relation quality. Lessons from Denmark and Sweden are outlined."
>
> Gorroño-Albizu & Godoy (2021: abstract)

This article can be considered as an ethical framework for socio-technical energy systems such as district heating systems. The article examines the potential for monopoly companies to abuse their position of power. We historically investigated the mechanisms that could indicate unfair behaviour of the district heating institutions in the past. Similarly, we explored the used mechanism that enhanced consumer power and promoted the implementation of institutional frameworks that promoted

fair conditions for customers. Based on the analysis of institutional configurations of district heating systems in Denmark and Sweden, our research strategy was to investigate the various mechanisms that have contributed to or failed to promote consumer power. We applied a mix-method approach consisting of document analysis (consumer complaints, stakeholders' websites, legal documents), systematic literature review, and interviews with DH experts. Experts' insights on institutional frameworks and unfair conditions for DH consumers were fundamental to infer a possible causal relationship between cultural aspects and institutional conditions. The data was thematically analysed, focusing on institutional conditions, consumer power, unfair conditions, and indicators of a causal link between those. This enabled us to respond to the following research questions:

- What institutional conditions have been implemented in Denmark and Sweden related to the four dimensions of consumer power (explained below)?
- What issues indicating unfair conditions for DH consumers can be identified for the different institutional configurations and why?

The main arguments and theoretical approaches of the article were:

- *Most common ownership models:*
    - Denmark: Local initiative (1903-1978), followed the establishment of the regulatory framework (1979-1999), and finally the evolution of the regulatory framework (2000-present)
    - Sweden: Municipal regulation and prominence (1948-1995), followed by liberalisation and re-organization period (1996-2007), and finally re-regulated period (2008-present)
- *Four dimensions of consumer power in natural monopolies:* the analytical framework for consumer power (Hvelplund, 2007), proposes four categories of power:
    - "State regulative power": Refers to the regulatory mechanisms such as obligations of connection to the DH systems, heat profit, investments, and energy sources, among others.

    - "Ownership power": Customers can influence companies' decisions.
    - "Buying power": Customers have a choice of heating system.
    - "Communicative power": Customers have accessibility to information about the decisions of DH systems (the other three types of consumer power are interdependent on communicative power since, without transparency on information, any other power can be exercised).
- *Cultural dissimilarities* between the two countries drove different institutional frameworks: although both countries have similar cultures, differences were reflected in the preferences of ownership models. For example, DH in both countries, Sweden and Denmark, started with local initiatives, motivated by cheaper heat and environmental aspects (lower air pollution and indoor comfort). However, while DH in Sweden was mostly municipally owned (1948-1995), in Denmark, municipal ownership was responsible for all large and medium-size DH systems and cooperatives
- *Fair institutional conditions for customers.* We considered that fair conditions are satisfied when DH customers have satisfactory product quality (temperature, hours of availability), satisfactory customer relation quality (efficient communication channels), and reasonable heat prices (value for money, competitiveness compared to other heat systems).
- *Cultural aspects were underlying institutional conditions:* The institutional conditions for customers differ based on the culture and values present in Scandinavia. Trust as a cultural trace induces the institutions to adopt fair conditions, enhancing consumer power in relation to those systems and adopting models of transparency and open participation. We believe that there is a link between the dimensions of consumer power and the culture of trust that underlies the Scandinavian societies.
- *Context plays a role in the strategies adopted for developing energy transition projects:* Denmark's DH institutional and economic models are primarily based on consumer ownership. Meanwhile, Sweden largely

focuses on commercial DH systems. This influences the participation and involvement of customers, where the market organizes customers' subscriptions to a specific energy company instead of another.

The main article results were:

- *Regulations need to enhance consumer power:* Free choice of heat supply (recently, the mandatory connection rule was changed to non-mandatory) is not enough to guarantee DH companies to set reasonable prices. Thus, regulations should be introduced to guarantee consumers' power.
- *Ownership models choices should mind short and long-term effects:* Market competition (linked to free choices of heat supply) could result in additional costs for society (e.g. subsidies for companies, cost reduction can require more maintenance in the system in the long term).
- *Regulations based on costs do not guarantee low heating costs:* Cost-based regulations must be accompanied by high ownership power and communicative power to guarantee reasonable heat prices.
- *Cultural aspects may influence the models of ownership:* Local consumer cooperatives and local municipalities companies can cooperate in developing and running DH systems.
- *Ethical aspects:* Related to the monopoly nature of the DH is the question of whether those organizations should be able to make a profit, whether the DH owned by municipalities can collect taxes directly, and whether the profit should stay with the local community.

Our main conclusions and contributions were:

- We explored the causal link between the institutional conditions (that promote the dimensions of consumer power) and the unfair conditions for consumer power during the period from 1903 to the present for Denmark and from 1948 to the present for Sweden.
- High consumer power, local ownership, transparency, and communication are necessary to reduce DH prices.
- Ownership models influence price and transparency, consequently influencing customer power.

6.5. SOCIOMATERIALITIES INSIGHTS ON DISTRICT HEATING SYSTEMS

This section contributes with a description and synthesis of district heating as sociomaterialities. More specifically, studying DH as a sociomaterial refers to focusing on the practices of energy experts and their organizations in relation to the socio-technical characteristics of those systems. It is first necessary to understand the social aspects entangled with the material aspects. For example, how do the energy experts perceive their influences on the development of DH systems? What socio-cultural aspects benefit and hamper those systems' development? Sociomaterial analyses on DH revealed that the system depends, amongst others, on the heat demand density and, hence, on the connection of consumers to the system. Thus demographic density and heat resources access make the system economically feasible, and the connectivity rate is important to maintain the heating prices low. In Denmark, those systems have a few hundred to several thousand consumers. A lay understanding of the function of DH systems is that the end customers receive hot water, which is collectively distributed via pipelines. The complexity of the infrastructure is one of the factors that make those systems natural monopolies of a local nature. This implies that little or null competition is in place, differing from other systems such as those responsible for the provision of electricity or gas where customers can choose the provider. The investment costs for DH systems are high; thus, they are more viable when there is a high connectivity rate (rural areas can be neglected). The local characteristics of those systems require cooperation from stakeholders (heat producers, housing associations, etc.) to guarantee the systems' development and attend to the heat provision with security. The small size of the local market, together with the constraints of the network infrastructure, mean that unbundling of heat production, distribution, and retail does not lead to lower heat prices. The natural monopoly characteristic also means that one single company often oversees heat production, distribution, and retail. Misusing their monopoly position can happen if institutional regulations do not cover all the aspects influenced by those organizations. If dissatisfied with the service they provide, consumers have no other option for DH suppliers. The only option is to invest in another supply system. An additional risk to

consumers of DH is that they need to remain vigilant on the consumer rate, meaning that if a consumer residence decides to adopt individual boiler solutions, the heating system may increase the service price. Furthermore, if the municipality is not continuously investing in heating technologies, this can result in low heat security or rising prices. Since heat is considered a basic need in countries with extremely low temperatures, it is conventional for consumers to actively or passively participate in the decisions of those organizations. In Denmark, considering heating a basic need, DH organizations cannot profit from it. Even so, other decisions, e.g., which company is providing the heat source, require those organizations to be fair, transparent and trustworthy over the decisions to guarantee the cooperation between customers and DH organizations while resulting in environmental advantages.

All in all, we have seen how the social (organizations, consumers, choices of heating system, urbanization development, experts, trust, transparency) and the material (prices, connectivity rate, energy source, companies' development) cannot be seen (or studied) as separate elements. Such a description is an exemplary example of the sociomaterial elements of socio-technical systems.

6.6. ROLE OF SOCIAL TRUST IN DISTRICT HEATING SYSTEMS DEVELOPMENT

Based on the article:

> **Godoy, J.**, Gorroño-Albizu, L., **Expert´s Perceptions of the role of trust in district heating systems: Unravelling the cases of Sweden and Denmark** (in preparation)

The article´s abstract reflects the approach adopted for understanding the fair institutional conditions of DH systems:

> "The potential contribution of district heating (DH) to reducing energy sector emissions can be hampered because DH systems are difficult to establish due to tensions arising from natural monopoly characteristics and citizens' right to democratic choice. Sweden and Denmark have a well-established DH industry and a high level of

> societal trust, which can indicate to be a combination of characteristics that guarantee the successful development of the DH sector. Nonetheless, few studies have been conducted to understand the relationship between the culture of trust and the development of district heating systems. Trust is pointed out as promoting the development of socio-technical systems by reducing projects' complexities and increasing cooperation among states, citizens, communities, organisations and institutions. We aim to understand the role of trust in the development of district heating in Sweden and Denmark. We believe that broadening the understanding of trust in relation to DH systems may assist other countries in increasing citizens' trust by adopting similar mechanisms and advancing district heating development. Here, we investigate the perceptions of DH experts about the effects and role of trust on the development of DH systems. According to our thematic analysis, district heating experts believe trust is a key social mechanism for maintaining democratic relations and fair district heating institutions. The institutional contexts of Sweden and Denmark differ in terms of business models, decision-making, transparency, and consumer power. Yet, they are historically similar in the nurturing of social and institutional trust."
> Godoy & Gorroño-Albizu (2022: abstract, article in preparation)

This article focuses on unravelling the expert's perception of the role of trust in district heating systems. Sweden and Denmark have high rates of DH connectivity and have developed institutional conditions that promote fair conditions for customers over the years. The role of social trust still seems to be a black box, mainly for other countries that wish to follow the example of DH from Denmark and Sweden. Since Scandinavia has the highest social trust worldwide (Rothstein & Stolle, 2003), we explored in this article the role of trust as a cultural trait in developing DH systems. As a first step in opening the black boxes of informal institutional conditions regarding DH deployment, we analysed the perceptions of Swedish and Danish DH experts about the role of trust in the development of DH. Insights from DH experts' perceptions

about the role of trust allowed us to understand how a culture of trust has influenced the institutional characteristics of DH, as well as advance the knowledge on the importance of aligning institutional structures with the culture that socio-technical systems are embedded in. We adopted a mixed method approach, formed by a structured literature review (peer review articles, book chapters), document analysis (consumer complaints, reports of the DH associations), and expert interviews. The interview data (more than 15 hours of recorded data) was thematically analysed and combined with the data from document analysis and the structured literature review.

The main theoretical arguments of the article are:

Cultural traces play a role in developing technological structures, institutions, business, and ownership models. This means that social capital (cultural, symbolic) in societies influences experts' behaviour (Bourdieu, 1983). Designing fairer institutional conditions is linked with the cultural characteristics of the underlying system. For instance, in Scandinavia, the trust and trustworthy behaviour of energy experts and businesspeople influence the participation of customers in the decisions and development of those systems. Trust appears to be at the core of the Scandinavian economy, its corporate strategies and its businesspersons. It is a reflection of society's demand for transparent governance and corporations.

When studying trust, it is relevant to consider that trust and distrust can coexist simultaneously (Mcknight & Chervany, 1996). However, distrust is not symmetrical to trust, nor the opposite. As we mentioned above, while trust is the feeling that things will go well, distrust can be considered a social mechanism indicating disagreements, conflicts of interests and controversies, and can be an alert about risky situations. Trust, as a subjective social value, can be traced by looking at the interrelated concepts that underlie a trusted behaviour (Rayner, 2010) or comes in subconstruct practices that interdepend on one another. Characteristics associated with trustworthy behaviour are transparency (Van De Walle & Six, 2013), autonomy (Mcknight & Chervany, 1996; Taddeo, 2010), liability (Goedkoop & Devine-wright, 2016), and fairness (Rayner, 2010).

The main article (preliminarily) results were:

- *Implicit Rational Distrust:* lock-in effects and the monopolistic characteristic of DH systems can generate an implicit rational distrust.
- *Active participation versus passive participation:* those characteristics work as a mechanism for identifying customers' satisfaction with the decisions. Active participation in the DH meetings and public hearings shows that a rational distrust is in place. Thus, the customers remain vigilant about the decisions. In comparison, passive participation can indicate trust in the decisions.
- *Risk perception:* citizens' trust in DH is also associated with their identification of risks. “Trusting in technology or believing that a technology has desirable (i.e., trustworthy) attributes seems reasonable because we talk about trusting in non-human entities in everyday discourse” (Lankton, 2019 p. 881). Aware of this, the DH institutions tend to instantly address failures that can occur in the functioning of DH systems to guarantee that citizens will not distrust the DH systems.
- *Trust in institutions and energy experts:* Citizens trusting that DH institutions will act on customers' best behalf is believed to influence a high connectivity rate of DH systems.

Preliminarily article's conclusions and contributions are:

- Energy experts perceive trust can reduce the complexity of the alignment of institutional and technological configurations.
- The district heating systems of Sweden and Denmark are embedded in a trust culture that exists due to a process of nurturing, communication, participation and ethical practices.
- Experts perceive that customers' willingness to adopt district heating as their heating/cooling solution is influenced by the perception of the trustworthiness of institutions.

6.7. SUMMARY OF THE CHAPTER: CULTURAL ASPECTS AND SOCIO-TECHNICAL SYSTEMS DEVELOPMENT

The purpose of this chapter was to explore the connection of trust, customer power and fairness in the development of district heating systems. In addition, the case study serves as an example of socio-cultural factors shaping the development of socio-technical systems. The main conclusions of the chapter are:

- Customers' power can be enhanced through institutional frameworks where fairness conditions are at the centre of the experts' decisions.
- Institutional conditions that allow higher consumer power favour lower DH prices.
- Denmark and Sweden applied different regulatory frameworks and governance models for DH.
- Culturally, those countries have similarities that are reflected in the traditions of ownership models, responsible policy markets and democratic values.
- Transferable lessons can be used to enhance the DH systems of other countries.
- From the study of the role of social trust in the development of fair conditions for district heating, we find that trust plays a key role in facilitating the development of the projects and reducing complexity.
- Similarly, rational distrust occurs when customers are not comfortable with the decisions being carried out.
- A mechanism utilized by customers to deal with unfair decisions and disagreements is having more active participation.
- The mechanism energy experts highlight that customers use to demonstrate concern over the decisions is by adopting both active and passive participation. Thus, customers will be active in the meetings and consultancy mainly when they need to be vigilant over the decisions being taken. On the other hand, a passive role is adopted when customers judge that the decisions are in accordance with their needs. Such evidence is from Denmark.

Insights from agential realism and sociomaterialities:

- Sociomaterialitites help to visualize the many aspects influencing the development of socio-technical systems as a whole, bringing those aspects to the same domain.
- The case explored in Sweden, and Denmark shows a tendency of citizens to influence the decisions greatly over the district heating system. Thus, the decisions of how and what socio-technical infrastructures

In the next chapter, the perceptions of energy experts on the energy transition process are understood by analysing their proposals in scientific research in relation to the digitalization of the energy sector.

CHAPTER 7. POST-DIGITALISATION OF THE ENERGY SECTOR

Decarbonization, democratization, and decentralization of the energy sector are leading to the emergence of business models where digitalization is pointed out as having a pivotal role (Luisa et al., 2018). This chapter's interest in the digitalization narratives is on the collateral effects of such digitalization of the energy sector, which, paradoxically, entail centralization of information, the commodification of behavioural data, and potentially an erosion of trust in societies. As seen in the previous chapter, trust facilitates cooperation, reduces complexity, and is a tradition in Scandinavian societies. I first focus on theoretically analysing the methods and techniques in development for the digitalization of the energy sector, correlating those with the emergence of big data analytics and their effects on the culture of trust in Scandinavia. Furthermore, I discuss ethical perspectives emerging and required for regulating the practices of digitalization of the energy sector. Since deploying smart meter devices is a requirement of the EU (Zhou & Brown, 2017), I specifically review the emerging practices of big data analytics over data collected from householders' behaviour through smart meters. The four main contributions of this chapter are:

1. Mapping the narratives and practices of the digitalization of the energy sector.
2. Tracing the practice of surveillance capitalism and verifying the likelihood of its occurrence in the energy sector. Surveillance capitalism is a “new economic order that claims human experience as free raw material for hidden commercial practices of extraction, prediction, and sales” (Zuboff, 2019, p. 7).
3. Discussing disciplinary research performances and self-perpetuating disciplinary practices by tackling the problem with an interdisciplinary perspective.
4. Exploring socio-technical aspects of digitalization and how energy experts’ energy practices shape energy cultures in societies.

Emphasis is given to the material-discursive practices on academic disciplinary outcomes due to their capacity to reveal the entanglements of matter and meaning. This means that I explored human factors in the technoscientific practices of the digitalization of the energy sector, aiming at "dissolving the boundaries between the human and the nonhuman", an approach also used by Donna Haraway in her book "A Cyborg Manifesto" (Lupton, 2019 p. 1999). Practices that allow the digitalization of the energy sector are discussed by looking at the possible collateral outcomes those practices can have, as well as their interferences in the culture of trust in Scandinavia. Ethical aspects (as an ethico-onto-epistemological phenomenon) of the technoscientific solutions for climate change are also discussed.

Not all data hold the same potential for surveillance capitalism. Datasets of the energy sector are based on two sources: systems data and customers and suppliers data (Rhodes, 2020). The former is related to energy flows through the electricity network, weather forecast, and location of assets such as distributed generation and storage (Rhodes, 2020). The latter is related to energy usage and customer data (periods of time, amount), accessed by suppliers through smart meter devices and related to the mechanism of demand response (Rhodes, 2020). The interest of this chapter is on big data analytics practices concerning the data from the supplier side (customers' datasets). In the next section, I present the practices leading toward the digitalization of the energy sector.

7.1. SOCIOMATERIALITIES IN THE DIGITALIZATION OF THE ENERGY SECTOR

The transformation of the energy sector consists of sociomaterial practices such as the digitalization of energy systems. Analysis of sociomaterial practices is as important as the performativity of several actors in the digitalization of the energy sector since "subject and object do not preexist as such, but emerge through intra-actions" (Karen, 2007 p. 89). Digitalization of the energy sector starts with the integration of an information and communication technologies (ICTs) infrastructure in the energy grid. With ICTs, it is possible to isolate areas of the grid in case of fault and identify energy loss and thief of energy through load monitoring. Such infrastructure is also what allows consumers of energy to become prosumers, as well as the integration of

decentralized production. Such features can empower new types of ownership models for energy businesses (Van Summeren et al., 2021). For example, those led by citizens and community energy projects (also called Virtual Power Plant (VPP) are (considered a portfolio of distributed energy resources (DER) (Van Summeren et al., 2020)). The narratives of smart grid transformation mostly centre on the benefits of integrating renewable energy sources and allowing a cross-sectoral integration into the electricity grid (transportation, DH) (Lund et al., 2017). Smart grids allow decentralization of production and consumption, ideal for integrating renewable energy sources, such as wind and solar, and dealing with the intermittency of these natural resources.

However, energy experts' practices are key to the pathways of sustainable transformations, and their practices are to be centred on the decarbonization, decentralization, democratization and digitalization of power infrastructures (Silvestre et al., 2018). Those areas are considered to be interdependent on each other. For example, narratives suggest that the democratization of energy systems can be achieved by the decentralization of electricity production (also called distributed generation) (Kester, 2016a). The underpinning argument is that geographically spreading the production of energy allows citizens active participation in the business models as key stakeholders (as prosumers (IPCC, 2018)) and more community engagement (Perez-DeLaMora et al., 2021). In technical terms, decentralization is partially possible due to an infrastructure of transmission that allows bi-directional flows of energy and information. This allows producers (like citizens) to sell energy back to the grid. However, decentralization is still often described as a future project or outcome of the infrastructure being implemented now (Silvestre et al., 2018). Another narrative on digital transformation expresses the benefits of integrating renewable energy technologies (Silvestre et al., 2018). The emergence of economic markets reinforces the narratives favouring data collection and processing. However, a surplus of this digitalization of the energy grid is users' data (including data from spheres that used to be considered personal), boosting the culture of big data analytics in societies due to the possibility of data being used to derive second-order insights

(e.g. behaviour of citizens when using energy). As Johannes Kester (2016a) argues, the decentralization of energy production became a re-centralization of knowledge. My article, together with colleagues[31] (Godoy et al., 2021), investigates practices of digitalization in the energy sector and shows how the centralization of knowledge was thrust by a culture of surveillance, which entails collecting, processing and commodifying users' data. Such practices can work as a form of power and control. Thus, the democratization of energy systems can be harnessed for surveillance capitalism practices in the energy sector, which in turn has the potential to change the cultures of trust in societies.

7.2. CITIZENS AND THE DIGITAL INFRASTRUCTURE IN THE ENERGY SECTOR

As explained above, the integration of a digital layer in the energy grid is underway. This allows connecting energy consumers to the energy grid. The deployment of smart meters at consumers' sites, like people's houses, industries, and the public sector, is the first step to achieving smart grids ((Solomon & Krishna, 2011); (Ballo, 2015)). The spreading of digital infrastructures to the energy sector shows how datafication of societies is becoming ubiquitous. However, with the emergence of surveillance capitalism practices, concerns are rising about the use of information and communication technologies (ICTs), as well as ethical questions on how such practices are changing our understanding of the world and of ourselves (Floridi, 2015). The online manifesto edited by Luciano Floridi (2015) explores what it means to be human in a hyperconnected era. The blurring of humans' distinction between reality and virtuality, between humans, machines and nature, and a shift of privacy domains were some of the transformations mentioned (Floridi, 2015). However, the human factors related to the concentration and processing of behavioural data still have societal consequences for individuals which are not fully understood. Dichotomies exist in relation to the human factors in the digitalization of societies.

[31] In cooperation with my formed co-supervisor (Kristian Høyer Toft) and my formed supervisor (Kathrin Otrel-Cass) and now co-supervisor. The interest for the digitalization of the energy sector emerged while I was doing the industrial internship, the topic was of high importance for that industry.

Some examples of such dichotomies are: data liberalisation vs data socialism, data privacy as being a concept of the future vs being a concept of the past, laws and censorship vs self-control and freedom, digital literacy vs digital society.

Digitalization of the energy sector, as a socio-technical matter, consist of the entangled technical (ICTs, smart meters) and societal (more involvement of citizens in energy production, control of consumption) factors. Societal participation consists on giving the users visibility about their energy practices, allowing them to control how they spend energy and how much it costs, a process called demand-side management (DSM). Smart meters role is one of a device for controlling the consumption practices. However, this also means users´ energy practices are recorded, stored and can be analysed for understanding users' behaviour and preferences.

Smart meters implementation can be motivated by ambiguous purposes in the digital transformation of the energy sector. This is because understanding users´ energy behaviour can be abused for surveillance capitalism practices. Users' data can be stored and are under the responsibility of the distribution system operators (DSOs). DSOs are usually natural monopolies (as explored in the chapter 6). This means that they work in settings where there is no competition or other grids as an alternative for users to connect to due to high costs and the inefficiencies this would imply. As Johannes Kester (2016a) argues, although there is a decentralization of production, consumption and distribution, power in the energy sector remains centralized.

The connection I make in this chapter is between the practices of big data analytics and the emergence of the practices of surveillance capitalism. See in the next section a summary of my review with colleagues[32] (Mannov, Andersen, et al., 2020) on Shoshana Zuboff´s (2019) book: The age of surveillance capitalism: the fight for a human future at the new frontier of power (704 pages). The understanding of the practice of surveillance capitalism is fundamental to the exploration of the spreading of such practice into the energy sector.

[32] Cooperation carried out with my colleagues Adrienne Mannov and Astrid Oberborbeck Andersen, while I was part of the department of Learning and Philosophy in the Aalborg University.

In the following section, I present the main ideas of our critical review of surveillance capitalism.

7.3. EMERGENT MARKETS AND SURVEILANCE CAPITALISM

Based on the article:

> Mannov, A., Andersen, A. O., & de **Godoy, J**. (2020). **The age of surveillance capitalism: The fight for a human future at the new frontier of power.** Tecnoscienza: Italian Journal of Science & Technology Studies, 11(1), 109-113.

In this critical review, we identified key concepts which underlie Shoshana Zuboff´s (2019) theory of surveillance capitalism. The central critique that gave rise to the term is about the practices of commodification of personal information with the purpose of profit. She considered that on such process, human experience is considered as free raw material, generating concentration of wealth, knowledge, and power. In her views such instrumental power of the practice of surveillance capitalism is a threat to human nature. Shoshana Zuboff, as a social psychology scholar, explored the effects of contemporary computing application on society. She managed to delivered a piece that represents an "in-depth technical understanding and broad, humanistic scope" (Bridle, 2019). The practice of surveillance capitalism is presented as a social and material practice, representing an example of interdisciplinary thinking in science, technology and society (STS). My decision of engaging in reviewing such work was to contribute a deep understanding of how far the consequences of such practices can go if spread to the energy sector. Key arguments of Shoshana Zuboff (2019) about the practices of surveillance, useful for reflecting about the digitalization of the energy sector are:

- Individual users´ data exhaust is a resource for tech companies. Data exhaust is the bi-product of users' behaviour, such as metadata which might be considered waste material, but it is utilized by companies for learning about and improving the personal experience of users.
- Users' profile information and behaviour surplus to sell ads (investment into revenue).

- The spreading of such a practice develops with the cooperation of state actors and tech companies.
- Tech-companies are re-thinking avenues for profit where behaviour analysis can bring new commercialization opportunities.
- Surveillance capitalism is associated with an opportunity or means for behaviour modification and commodification brought by ICTs.
- Surveillance capitalism has an instrumentarian power where the instrumentation and instrumentalization of behaviour is used for the purpose of modification, prediction, monetization and control (Zuboff, 2019 p. 352).
- An effect of the economies of action that surveillance capitalism bring is a focus on the individualization of consumption.
- Concentration of information and knowledge, DSO´s own user´s data. (Kester, 2016a).
- Mental health problems associated (Zuboff, 2019).
- Perceiving users' data as a product can result in users progressive changes in behaviour being the product (e.g. shaping energy usage behaviour).
- Surveillance schemes can lead to the use of the information for the wrong purposes, such as shaping civic and democratic choices, as in the Cambridge Analytics case of manipulation of individuals' votes in 2016 (Ward, 2018).
- “Surveillance capitalism and its societal effects represent an unprecedented threat to Enlightenment values of humanity” (Zuboff, 2019 p.323).
- Information users never intended to be disclosed can still be inferred through analytics (Zuboff, 2019). For example, energy data can reveal when a user is at home and what appliances the user has used.
- Data on energy usage can be used for profiling and clustering citizens (e.g. psychographic data) (Zuboff, 2019).

The following section explains the article where the practice of surveillance capitalism in the energy sector was explored.

7.4. DATA ANALYTICS OF THE ENERGY SECTOR AND SURVEILLANCE CAPITALISM

Based on the article:

> **de Godoy, J.**, Otrel-Cass, K., & Toft, K. H. (2021). **Transformations of trust in society: a systematic review of how access to big data in energy systems challenges Scandinavian culture.** *Energy and AI*, 100079.

The article´s approach, as expressed in the abstract was the following:

> "In the era of information technology and big data, the extraction, commodification, and control of personal information is redefining how people relate and interact. However, the challenges that big data collection and analytics can introduce in trust-based societies, like those of Scandinavia, are not yet understood. For instance, in the energy sector, data generated through smart appliances, like smart metering devices, can have collateral implications for the end-users. In this paper, we present a systematic review of scientific articles indexed in Scopus to identify possible relationships between the practices of collecting, processing, analysing, and using people's data and people's responses to such practices. We contextualise this by looking at research about Scandinavian societies and link this to the academic literature on big data and trust, big data and smart meters, data ethics and the energy sector, surveillance capitalism, and subsequently performing a reflexive thematic analysis. We broadly situate our understanding of culture in this context on the interactions between cognitive norms, material culture, and energy practices. Our analysis identified a number of articles discussing problems and solutions to do with the practices of surveillance capitalism. We also found that research addresses these challenges in different ways. While some research focuses on technological amendments to address users' privacy protection, only few examine the fundamental ethical questions that discuss how big data practices may change

> societies and increase their vulnerability. The literature suggests that even in highly trusting societies, like the ones found in Scandinavian countries, trust can be undermined and weakened."
> Godoy et al. (2021: abstract)

In this review article, we explored the digitalization of the energy sector and the potential use of data from spheres that were considered private as a source for behaviour commodification. We analysed the threats surveillance capitalism poses to Scandinavian societies and how this could challenge their culture of trust. The article entails interdisciplinary research. Although we did not mention the use of the agential realism theory in the article, it is possible to see in it a diffractive reading of the human-nonhumans factors. The diffraction reading was organically used to study the digitalization of the energy sector, which was based on the reading of the status of computational developments and their interferences on the Scandinavian cultures of trust. The central arguments of this interdisciplinary research were the following.

- Surveillance capitalism, and data gathering technologies are ubiquitous in societies.
- People´s sensible information cannot only be collected with smart devices, but also inferred from raw power consumption data.
- Energy industry, as a tech industry, is highly prone to exploit people's data for commercial purposes.
- Scandinavian trust is based on transparency between citizens and organizations. If their core values differ, democracy values could be at risk.

The main research questions of the study were:

- Who has control over data? Should it be restricted to only those who have the material, cognitive, and financial resources to access and process big data [14], so that they can potentially make unauthorised decisions on behalf of others?
- How do big data harvesting, analysis, and processing challenge the concept of trust within societies?

Our main findings were:

- The investigation of surveillance capitalism practices and its effects showed the importance for those with power and control over energy users' data to be trustworthy when processing and stewarding people's data.
- The systematic literature review was shown to be an effective methodology for interdisciplinary inquires.
- According to our review, the majority of the published research focuses on technical issues such as architectures for privacy protection or security protocols for data protection.
- Analytics of data collected through smart meters is in its early stages, but the emphasis is on optimization strategies. The vulnerability of users to technical solutions for protecting people´s privacy was evidenced in our review.
- In Scandinavian countries, the distribution system operators (DSOs) control data collected from users by smart meters.
- Although in Scandinavia, users tend to trust the core institutions that collect data, they are wary of the actions taken on their behalf (existence of a rational distrust).
- Trust improves cooperation among energy providers, distributors and customers, accelerating the energy sector´s digitalization.
- Because the majority of the research produced had a focus on the technical areas, regulations and ethical frameworks require much more attention to guide and regulate the practices over user data in general, not just the ones related to surveillance capitalism.

In the next section, I discuss the ethical implications and the role of energy experts.

7.5. ETHICS AND THE ROLE OF ENERGY EXPERTS IN THE DIGITALIZATION OF THE ENERGY SECTOR

By engaging with interdisciplinary matters brought by STS fields, energy experts can understand the need for public debate around social phenomena, like surveillance capitalism and its consequences. Surveillance capitalism in the energy sector can happen as a spontaneous or emergent phenomenon, for example, due to performances that normalize and develop its underlying and necessary material-discursive practices.

There is no requirement for a specific group of actors premeditately articulating the spread of smart meters for surveillance and data profitability. Hence, energy experts have the role of predicting the likely consequences and effects of the transitions of energy systems. They should be able to identify the risks of their practices and be active when ethical challenges arise while producing their outcomes, especially when those have a direct social impact.

Computational technologies' development towards commodifying users' behaviour for profitable purposes may decentre the focus of the energy transition and potentially blur trust in societies. Similar phenomena have been documented, like the commodification of non-human natures with the conversion of land into private property, which is an example of the "*financialised ecology-commodity"* pointed out by Sullivan (2013, p. 210). Furthermore, the widespread adoption of technologies like smart meters can also result in variations in price and behaviour, which may drive some users into fuel poverty (European University Association, 2017).

An actual problem is the loss of trust citizens have in the energy transition since the impact of commodifying personal information is a cause of mistrust in many societies. Digitalisation is spreading to the energy sector, requiring citizens to trust institutions that collect and analyse people's data, and people are vigilant due to increasing surveillance capitalism practices. Scandinavian societies have normalized the digitalization of systems where it is conventional to collect datasets in many areas, like biobanks and online banking.

Another area of discussion is the concentration of power and manipulation of markets that can be achieved by companies that hold data. Such user behaviour data can be of interest to third parties and can further be used for control and for market manipulation. Furthermore, integrating energy demand response in energy markets can concentrate wealth in the companies that have the possibility to store energy or produce energy. For example, countries that run on solar power will need to pay high prices in high-demand periods and sell the energy at significantly lower prices during other hours of the day. Such market manipulation can proliferate monopolies. Thus, Consumers' information is of particular interest for companies with data-based business strategies like those of Facebook or Google, who might sell private

information to advertisers. If smart meter devices are connected to cell phones, it becomes easy for users to receive offers of products they did not know they needed.

The main question that poses not to be solved is how are we going to frame the energy transition considering that a post-trust era was started thanks to the abuse of data analytics on users' personal information from social media, which has been sold to advertising companies. This practice has led to many court cases against companies such as Facebook and Google, who turn the responsibility of protecting users' private information on the individuals. I wonder how much is the energy sector going to advance and instaurate such practices with the help of cooperation among companies and governments? Would a neoliberalism ideology follow, where the responsibility of protecting data and the data that can be inferred is transferred to the individuals?

Disciplinary performance on the emergence of technological practices that violate basic human rights: There is a disciplinary performance associated with the fast-spreading of surveillance capitalism to many sectors (including the potential of this to happen in the energy sector). While technical sciences fields focus on advancing the technologies, improving the performance of data analytics and on the process of digitalizing societies motivated by a green energy economy, fields of social sciences focus on the effects of surveillance practices on society, and political sciences need to deal of balancing the technological development with the potential risks.

> "We need laws that reject the fundamental legitimacy of surveillance capitalism's declarations and interrupt its most basic operations, including the illegitimate rendition of human experience as behavioural data; the use of behavioural surplus as a free raw material; extreme concentrations of the new means of production; the manufacture of prediction products; trading in behavioural futures; the use of prediction products for third-order operations of modification, influence, and control; the operations of the means of behavioural modification; the accumulation of exclusive private concentrations of knowledge (the shadow text); and the power that such concentrations confer"(Zuboff, 2019 p. 219).

The next section summarizes the findings of the chapter.

7.6. SUMMARY OF THE CHAPTER

In this chapter:

- I presented the main arguments of out review of surveillance capitalism, drawing some connections such practice can posit for the energy sector.
- I analysed how the digitalization of the energy sector is being orchestrated and the main arguments supporting this transformation.
- I analysed the challenges that the digitalization of the energy sector can have for society.
- I reflected the use and efficacy of smart meters for the purpose of decreasing the demand and informing citizens.
- I explored the threats of surveillance capitalism to societies.
- I raised ethical questions not explored yet concerning the energy sector.
- I presented evidence for the need for an ethical framework to regulate the practices of digital analysis in the energy sector and how such a framework could be based on the justice theory of John Law.

CHAPTER 8. CONCLUSIONS: NARRATIVES AND ENERGY EXPERTS´ HABITUS

My focus for the last seven chapters was to argue for a complex orientation of paradigms and towards reflectivity on the role that energy experts' perceptions of the environment, their products, and processes play in the transformation toward sustainable energy systems. By exploring the energy experts' narratives, I have explored their subjective experiences in part one and the cultures on socio-technical configurations in part two. Such exploration allowed me to map the existing, emergent and required narratives on sustainable energy transitions to guide energy experts towards reflective abilities on their energy cultures.

8.1. EXISTING, EMERGING, REQUIRED NARRATIVES

In general, the narratives spotted in this thesis from the energy experts' practices and cultures highlight their power of influence on the future of energy systems. Their practices and performances influence directly the cultures their are embedded. Those cultures drive the decisions on the transformations of energy systems for societies. Energy cultures are driven by their perceptions of the products, processes and environment since energy experts practices become habitus embedded in energy systems. Energy experts' narratives are nested with ideologies, cultural and professional backgrounds, and their perceptions of the future. Their narratives are also constrained by the cultural contexts, delimiting what they can said and done (Lawler, 2002). However, those can also be limiting and hold the energy experts to old habitus. Thus, it is required that energy experts adopt reflective attitudes since decarbonizing energy systems toward just energy systems requires reimagining social structures (Clarke, 2015). Furthermore, energy experts need to embrace that we are responsible for the world we live in (Barad, 2007). Narratives examining energy experts' subjectiveness were explored in chapters 4 and 5. See a summary of the main findings:

Chapter 4 showed the existence of a theoretical consensus on the need for interdisciplinary and transdisciplinary research to tacked climate change. This is due to their robustness and the ability of those research approaches to integrate disciplinary research and produce transcendental outcomes while focusing on problem-solving in complex systems. Building knowledge beyond the traditional dichotomies of subjective-objective knowledge is required to move from disciplinary-centredness. However, challenges emerge once such theoretical knowledge spreads into the practical research domains and structures. Challenges spotted after tracing the practices and experiences of the ESRs on interdisciplinary energy research can be traced back to disciplinary lock-in and the structural format of institutions. Scholars' motivations for engaging in interdisciplinary research are related to 1) increasing knowledge of their core disciplines, a disciplinary habitus; 2) a visionary experts' perspective, where ESRs in formation to become energy experts strive for holistic rather than fragmented views of the energy problems. The primary learning outcomes from ENSYSTRA´s interdisciplinary projects are 1) the importance of social interaction, 2) the evidence that knowledge is remade in each inter- and intra-disciplinary meeting (helping to build knowledge bridges and new inquires), and 3) the need for individual and project-wise planning, preparation and coordination for achieving interdisciplinary outcomes.

Narratives that facilitate interdisciplinarity and transdisciplinarity in practice and help to change the disciplinary habitus and structural challenges are required. Based on a diffraction reading (Godoy et al., 2022), my framework has shown to be efficient in giving a structured way for ESRs to transcend knowledge production and raise beyond-mono-disciplinary inquiries. However, future work is needed on developing new regulations, policies and pathways to change how universities maintain disciplinary habitus through their structures. Research is necessary to dissolve the disciplinary lock-ins. Cultural re-structuration is required to promote interdisciplinarity and the valorisation of interdisciplinary outcomes and scholars. Such a reconstruction is needed to allow researchers to focus more on problem-solving and interdisciplinarity practices until the new structure becomes a habitus of academic traditions.

Chapter 5 mapped narratives generating the Anthropocene and how those influence the perceptions of energy experts when driving energy systems. Theoretically, existing narratives to deal with the human effects that caused the Anthropocene highlight the importance of deep ecology views (such as those raised in the NSR and proposed by Arne Næss (2005)) supporting all species to live in harmony. The theoretical formulations flourishing with the narratives of Anthropocene and posthumanism suggest an understanding of human-induced environmental disaster (Haraway et al., 2016), while acknowledging nature´s dynamics (Murphy, 2004) and nature´s agency in the capacity to react to our actions (Latour, 2018). Existing philosophies and currents of thought that go beyond the Greek-monotheistic-scientific views that reduce reality as one to be observed, expand the energy-humans-environment relations such as those of Indian-Buddhist and Chinese-Daoist (Oostveen, 2020).

Emerging narratives highlight that energy experts are those who are strategically positioned in social networks and can pave the way toward expanding society's views on energy-humans-environment matters (Parag & Janda, 2010; Zohar et al., 2021). Energy experts, as agentive participants, influence the transformation of energy systems through the entanglement of their practices and discourses. Thus, experts must be accountable for actions regarding the climate crisis, and their roles must extend local boundaries to include questions of global responsibilities. For example, energy experts in the NSR are responsible for the consequences of historical emissions. Consequently, they must strive to reduce suffering in the global south, following principles of liberty, equal opportunity, justice and emphasizing the need for redistribution of wealth (Rawls, 1971).

More pragmatically, required narratives are those that advance the translation of knowledge into practical actions that result in human-environment-nature harmony. Climate change experts like Burno Latour (2018) recognize the role of experts, such as politicians, to lead society towards sustainable futures, but guidelines can inform local practitioners on ways of living harmonious lives. Moreover, experts' consensus on responsibilities (local and global) and perceptions of the urgency of the climate crisis revealed to be necessary for accelerating actions on the energy transition.

Partially because the perceptions of energy experts on the urgency of the crisis can be influenced by the effects and risks they are exposed to in their environment. The mapping of energy experts' practices in this thesis revealed that the experts' perceptions directly influence their practices.

The second part of this thesis accounted for the practices of energy experts and their relation to the materialization of socio-technical systems.

Chapter 6 focused on historically analysing DH systems to determine practices that reflected unfair institutional conditions for the customers. It exposed how the energy transition to sustainable energy systems entails political-ideological, institutional and cultural matters (Berg et al., 2021; Diesendorf & Elliston, 2018; Strauss et al., 2013). The studied countries of Sweden and Denmark have institutions, cultures and business models based on community ownership (e.g., municipally owned DH systems). This was achieved over the years, during which those countries developed institutional mechanisms to guarantee cooperative models and the development of DH systems. Principles of trustworthy behaviour underline their political ideologies, models of institutions and cultures. In an entangled process, experts deal with the complexity of accommodating socio-technical factors without leaving customers in susceptible conditions. These countries have an emergent tendency for even more democratization of energy systems through continued practices that enhance citizen participation, transparency, fairness, fair prices, and social trust.

Trust works as a regulator of customers' participation in public hearings and meetings from the DH institutions. However, the communication channels can be improved. Although energy experts are equipped with principles of fairness, those principles can still be fortified and should be maintained as guiding principles for the DH energy experts' actions. Mechanisms that induce their reflective abilities should redirect them to look at the community's needs. Narratives that hold the citizens as stakeholders, instead of customers of DH systems are to be popularized. This requires more integration of cultural values of the community in the development of energy systems. The case explored in chapter 6 shows that cultural misalignment can work as a barrier. In the case of Scandinavia, social trust is not a silent tradition (Bourdieu, 1994). It is rather a complex one to document. However, energy experts understand the role of

trust, social trust and rational distrust as mechanisms for translating levels of customer satisfaction that can be used to guide their actions and as powerful mechanisms to equilibrate the power of models like those of monopoly energy systems.

In chapter 7, the focus was on the digitalization of energy systems. Existing narratives from technical sciences demand rapid digitalization of energy systems. STS disciplines, in contrast, highlight the importance of informed actions considering the consequences and requirements to digitalize without creating other black boxes due to the concentration of power and reliance on technological solutions for balancing/reducing energy demand. The protocols for energy data collection need to avoid dual-use since such energy metadata can lead to surveillance capitalism practices in the energy sector. The threats from such practice go from psychological effects to a concentration of wealth. Finally, regulations based on justice principles (Rawls, 1971) need to be further developed and applied in the energy sector.

8.2. ENERGY EXPERTS´ ENERGY CULTURES SHAPE THEIR PERCEPTIONS

Culture influences the perceptions of energy experts. Those perceptions determine their actions. Experts' actions impact the environment they are immersed in and engage with. All of these interdependent factors re-define energy experts' energy cultures. The energy experts' practices that inform energy cultures explored in this thesis involve techniques and methods for developing mono-disciplinary, interdisciplinary and transdisciplinary research; technics and processes that drive the digitalization of energy systems; mechanisms to understand the community needs and inform the community about the use of energy, etc.

Energy experts can drive and influence energy communities regarding the social practices (patterns of consumption and developments on the supply side) and the collective shared representation (underlying current of thoughts about the energy-environment-society relations) (Shove & Walker, 2014). Throughout the development of this thesis, I have evidenced that energy cultures, even those formed by early-stage experts undertaking training, indeed have the potential for rationalising their

decisions, influencing systems and institutional practices, and informing policies, as argued by Jacques Ellul (2015).

Experts must be aware of cultural path dependencies (Stephenson et al., 2021). For example, the community's expectations constrain energy experts' actions and limit the adoption of policy responses. Conversely, some cultural dependencies can favour ethical energy systems, such as those that embed a culture of trust and transparency in institutions and socio-technical systems. Cultural tendencies can also introduce conflicting views about the energy transition if, for example, dual use of peoples' data starts to take place and regulations are not in place to guarantee citizens' rights to privacy. Such actions can dismantle the trust in those societies and the energy experts driving the energy transitions.

Culture are not homogenised characteristics but formed by group of individuals who share common grounds (Lachapelle et al., 2014). Thus, the practices of groups of individuals drive cultures worldwide. My exploration of the energy culture of energy experts showed how the practices become habitus that becomes embedded in societies and systems. The exploration throughout the thesis was on the NSR energy cultures, thus, some analyses are context-wise. However, the importance of aligning socio-technical advancements with socio-cultural factors to accelerate development, understand the viabilities of projects and implement energy systems while democratizing energy in societies is general for socio-technical systems in transition. Hence, making the analysis and methods of this thesis valuable for a wide range of STS scholars, politicians, business persons, and interdisciplinary researchers.

The exploration of energy cultures emerging in energy research, for example, showed the impact of cultures on the research design and outcomes. Disciplinary cultures maintain and form disciplinary boundaries through material-discursive practices. Those disciplinary cultures carried practices that became disciplinary habitues of scholars, groups, and institutions. The perceptions of energy experts are formed by the practices and habitus of the disciplinary culture they are immersed in. Those perceptions are translated to scholars through the methods and theories they are exposed to and form their inquires and sense of urgency about problems and how their disciplines can contribute. Disciplinary cultures attract disciplinary capital for

institutions and researchers, which is necessary, but has been a mechanism that reinforces disciplinary habitus.

8.3. ENERGY EXPERTS´ HABITUS

I conclude this dissertation with an exploration of why a complex orientation to energy experts' habitus is necessary, particularly in light of current energy transformation paradigms and practices circulating in relation to both subjective experiences of energy experts and socio-technical systems. I contend that a complex orientation to energy experts' habitus can create a better trajectory for sustainable transitions. As energy experts' habitus shape experts' actions, perceptions and thoughts (Bourdieu, 1994), habitus is formed as a result of their practices, which shape social practices. Figure 7, summarizes how the areas that the energy experts' habitus has been explored and have an influence.

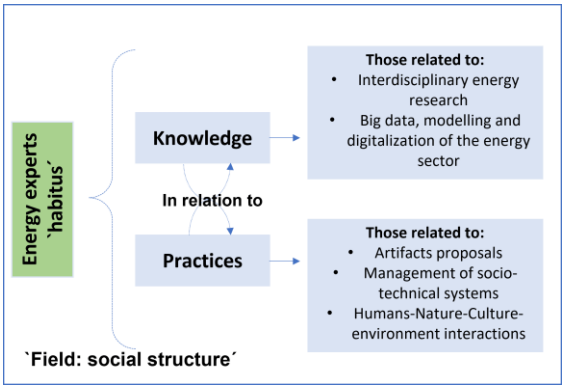

Figure 7. Experts energy habitus: knowledge and practices investigated in this thesis (based on Bordieu's theoretical understanding).

Pierre Bourdieu's (1994) studies on structure, habitus and social capital were explored in relation to this thesis with the aim to enhance energy experts' reflexive abilities on the power that their practices have on the energy transition. This led me to propose the concept of energy experts´ habitus. Energy experts' habitus as a concept, can influence energy experts' reflective abilities about their narratives and perceptions that drive actions of sustainable energy systems.

> ***Energy experts´ habitus is revealed through their material-discursive practices. Their practices carry their perceptions of the***

environment, cultures, imaginary futures and social structures. Thus, habitus must be reflected upon and modified if just sustainable energy presents are to be made.

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Appendix A. Interdisciplinary Model Collaboration

MODEL COLLABORATION FOR ENERGY SYSTEMS IN TRANSITION PROJECTS

BASED ON METHODOLOGICAL AND ORGANISATIONAL LESSONS IN THE INTERDISCIPLINARY RESEARCH AND COLLABORATION OF ENSYSTRA.

Deliverable 3.2 Best Practice Guidelines for Model Collaboration - WP3.

Project Number: 765515

Start date of project: 01-10-2017

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Marie Sklodowska-Curie grant agreement No 765515.

This report was written and coordinated by Jaqueline de Godoy (ESR 10).

The input data on this report had the contribution from the ENSYSTRA early-stage researchers (ESRs).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Marie Sklodowska-Curie grant agreement No 765515.

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1. INTRODUCTION

Projects aimed at interdisciplinary accounts like the Energy Systems in Transition (ENSYSTRA) are challenged by the need to discover and apply unconventional research methods. At times, this requires coordinating academic institutions, actors, and partners towards the same purpose. In ENSYSTRA, the primary goal is to train early-stage researchers (ESRs) in several aspects of the energy transition. Thus, the experiences in which the ESRs are exposed to matter for training will build experts with a holistic view.

Collaboration between several disciplines around a common research topic is a conventional definition for interdisciplinary research. To be effective however, frameworks based on a joint research agenda help overcome the challenges of crossing disciplinary boundaries (Pellegrino & Musy, 2017).

This guide aims to expose the experiences of the ESRs within the ENSYSTRA training, accounting for the best practice for model collaboration. He explores and collects such experiences based on methodological and organisational lessons in the interdisciplinary research and cooperation of ENSYSTRA. We construct this model collaboration based on the experiences of:

- the 15 early stage researchers (ESRs) who carried the research on several areas related to the energy transition;
- the interactions they had with ENSYSTRA stakeholders who worked in other institutions and cross-sectoral; and
- their experiences with the host institutional organisation and with the ENSYSTRA project who nurtured the collaboration process.

a. Objectives, the scope of this deliverable and questions for the assessment

The ‘Best practice guideline for model collaboration in the ENSYSTRA project’ is intended to offer concise instructions on orchestrating interdisciplinary collaborative practices with the specific goal of producing models. The guideline will reflect on how Ensystra ESRs were able to learn about and develop models by making connections between ideas and concepts across different disciplinary

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boundaries. In addition, the guidelines will reflect on how the ESRs learning allowed them to apply the knowledge gained in one discipline to another discipline to deepen the learning experience.

Knowledge is socially distributed, and the distribution of knowledge is socially structured, but the distribution and the structures within which it is produced and reproduced—often two separate things—have varied enormously (Turner, 2020). This guide exposes the practices, experiences, and challenges that allowed a broader impact on relevant scientific arenas that come together in energy system integration and transition management, from both, methodological perspective (such as the development of advanced modelling techniques), and advancing academic research and teaching (with enhanced cross-disciplinary interaction) in these areas.

We hope those insights from this experience can help manage collaborative research projects as the practice of interdisciplinary research increases challenge organisations to adopt new forms of methods and skills to develop knowledge (Wernli & Darbellay, 2016)."

b. Structure of this report

The results have been presented considering methodological aspects and organisational aspects. The methodological ones refer to the way the ESRs approached collaboration, their understanding of different models and ways of collaborating between disciplinary accounts and the ESRs motivations, challenges, and learning experiences. The organisational ones are related to the support the ESRs received from their host institutions, their secondment experiences and the ENSYSTRA project. In the discussion section, you can find the most important points presented. In the last section, we conclude, recommending collaborative practices for energy research projects.

2. METHODOLOGY

The model is based on the learning experiences of approximately four years of the project duration, from September 2017 till September 2021.

To assess the ESRs' experience, a questionnaire was applied. The questionnaire is divided into two parts, first one focus on the methodological accounts the ESRs have used during the ENSYSTRA Project (questions 1 to 3). The second part considers the organisational insights the ESRs were exposed to

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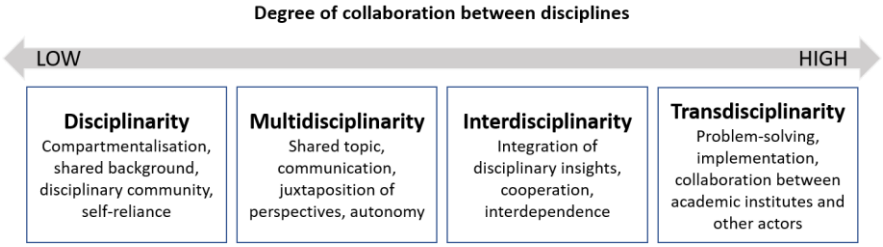
that helped build the interdisciplinary knowledge acquired during the project (questions 4 to 6). The questionnaires are based on the following questions:

1. **At the beginning of the ENSYSTRA project, collaborative research projects were planned together with ENSYSTRA colleagues (e.g. matrix available on appendix 1 or through the work packages meetings), with the secondment partners and the host university research group. Based on your experience, could you relate at least three projects where you worked as a team describing the process to do so, the details of the project and results expected/reached?**
2. **Please see the diagram below where it is defined the degree of collaboration between disciplines.**



Based on those definitions, could you describe which insights from other energy research areas you have juxtaposed, aggregated, or created to answer your PhD research questions?

3. **What were your motivations, challenges, and learning experience of collaborating in energy research projects?**
4. **Concerning your host institution research group, which practices had favoured the collaboration on energy research? In case you have little collaboration, could you describe the practices of your research group?**
5. **Related to inter-sectoral experiences, could you describe which insights and perspectives you gain with your secondments experiences? (e.g. participation in the organisation meetings, planned task together or writing projects)**
6. **How the ENSYSTRA project facilitate collaboration in your PhD research project? Were those experiences mainly with a low or high degree of collaboration (based on the definition in figure 1)?**

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3. RESULTS

a. Methodological aspects: experiences, theoretical learning, challenges and outcomes

i. Research experiences and collaboration encounters

- **ENERGY SYSTEM MODELLING (Work package 1)**

The ESRs part of the group working with energy system modelling was connected with the University of Groningen (RUG), Europa-Universität Flensburg (EUF), and the Chalmers University of Technology. The focus of this team was the integrated use and development of models covering all key energy supply options, energy carriers and infrastructure, including power, gases, heat and transport models, and further integration of demand-side aspects and potential changes in demand patterns including dispatchable loads. Individually the PhD´s research project goals were:

- "Develop **state of the art energy system models** for the North Sea region energy system and deliver high-quality **analysis of decarbonisation of the region**, including key topics such as the (potential) development of an offshore grid, the interaction between offshore wind and hydrogen, the feasibility of investments in energy islands and the inclusion of spatial data and technology learning curves in energy system models." (ESR1)
- Develop methodologies for building **sub-national renewable energy-based** and **sector-coupled energy system models** for the North Sea Region countries. (ESR2)
- **Modelling of Policies and Investments** for a large-scale Introduction of **Variable Renewable Power Production** (ESR3)
- **Spatiotemporal assessment** of the space suitability in the context of the transition towards renewable energy: The case of the **North Sea area.** (ESR4)
- Gaining insight into the possible arrangement, limitations, and potential of utilising the available technologies to achieve a **sustainable energy future for EU-28.** (ESR5)

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The ESRs under the projects mentioned above, working at the WP1, had several experiences considered disciplinary, interdisciplinary, cross-disciplinary, and cross-sectoral.

Collaborations with the **colleagues of ENSYSTRA** were to integrate the findings in the energy system models. For example, ESR1 shared that he "has developed different insights of the spatial analyses that Laura Gusatu (ESR4) already published, and key technological costs researched by Srinivasan Santhakumar (ESR7)" (ESR1). Such collaboration touches spatial and economic components of the energy model to bridge insights from our research projects to offer a new perspective on the energy transition challenges in the North Sea basin. According to Laura Gusatu (ESR4), "the advantage of the collaboration is based on the identified synergies between our projects, namely combining energy system modelling with the spatial parameters of offshore renewable energy deployment, the technological and economic aspects of offshore renewables" (ESR4).

Another relevant ongoing collaboration is in the area of hydro storage, nuclear power, and sector coupling in the future low-carbon European electricity system. Md Nasimul Islam Maruf (ESR2) and Xiaoming Kan (ESR3) cooperation aim to discover how hydro storage, nuclear power policy, and sector coupling affect the cost of the future low-carbon European electricity system. They brainstorm research ideas and developed a framework, all this under the supervision of Fredrik Hedenus and Lina Reichenberg.

The ESRs of this work package also had collaborations with the **research groups at the host university.** For example, the environment of the University of Groningen allowed many different interactions and synergies. Rafael Martinez Gordon (ESR) highlight that "the most notable one was the development of the IESA-Opt-NS model that was developed in close collaboration with other PhD candidates of our research group focused on a national level" (ESR1).

The work package demonstrates advanced skills for cross-sectoral collaboration. Examples of their **collaborations with secondment partners** were Md Nasimul Islam Maruf (ESR2) case, which worked with the researchers of the Energy Transition Unit (Netherlands) and VTT Technical Research Centre of Finland to review the power-to-heat (P2H) and thermal energy storage (TES) technologies. Maruf related that they "identified the critical P2H and TES technologies that will play a significant role in the energy transition. Then we characterised the key technologies and modelled them for optimisation energy models. An interim report of the research results was submitted to TNO" (ESR2). Laura Gusatu (ESR4) collaborate with the Institute of Marine Science, Italy. It resulted in a scientific paper accepted

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at the Scientific Reports-Nature. The success implied an initial agreement on the study's objectives, a concrete strategy including steps to be followed and roles assigned to the members of the team.

Another example of collaboration that started during the secondment of Xiaoming Kan (ESR3) in the Flensburg University is with Md Nasimul Islam Maruf (ESR2), Christian Fleischer (ESR5) and Prof. Olav Hohmeyer. Their project entitled Cool the future with solar PV aims at finding out whether it is cost-effective to invest in solar PV to meet the cooling demand. The study was accepted as a conference paper for the forthcoming IAEE conference. Furthermore, ESR3 and ESR2 are analysing the impacts of Green Battery as part of the ESR2 secondment at Chalmers University. Maruf said: "After a thorough literature review, we are analysing the impact of the green battery function on transmission line expansion, sector coupling, and national-level nuclear policies" (ESR2).

Christian Fleischer (ESR5) collaboration experiences are in modelling the transport energy demand and multi-year optimisation. While he was at Chalmers University, the former happened: "I worked on looking at methods to model the electrical demand of electric vehicles using GPS data of passenger vehicles. At the beginning of the secondment, I worked on a proposal for the secondment reviewed by my supervisor at Chalmers, which guided the collaborative work. There I had the opportunity to discuss with multiple experts in the field of transport sector modelling. The work conducted at Chalmers resulted in a description of two methodologies to model electrical vehicles using GPS data of passenger vehicles which was presented at Chalmers" (ESR5). The latter was during his secondment at ETH Zürich: "I worked on developing a multi-year optimisation model to analyse potential lock-in effects in the energy transition. The work began with preparing a detailed proposal on the task reviewed by ETH Zürich. The work was conducted primarily remotely using communication platforms such as zoom and Element to have bi-weekly meetings on the progress of the work. The work resulted in developing best practices to develop a multi-year optimisation model" (ESR5).

Another opportunity to **collaborate was contributing to the ENSYSTRA deliverables**. All the ESRs contributed to the policy briefs and the quantified scenarios deliverable. Md Nasimul Islam Maruf (ESR2) described his process with the policy briefs: The policy brief process was initiated during the Stavanger workshop in 2020, where thematic teams were formed and guided by the policy group and by Chalmers. For example, ESR2 collaborate with ESR6 and ESR15 on a policy brief on the role of advanced biofuels and carbon capture to pave the way for the EU climate goals. ESR 6 took the lead on the policy brief writing, with ESR 15 reviewing the contents and provided any additional information. A similar experience was related by Christian Fleischer (ESR5): I had the opportunity to

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collaborate with Jinxi Yang (ESR 12) and Andrew Kilmartin (ESR13) on a policy brief detailing the benefits and challenges of using Interconnectors in the North Sea region. ESR13 took the lead on writing the policy brief, with ESR 12 and myself reviewing the contents and providing additional information (ESR5). The policy brief was presented to the ENSYSTRA group and published on the ENSYSTRA website.

- **NEW TECHNOLOGIES AND DEVELOPMENT PATHWAYS (Work package 2)**

The ESRs part of the group working with new technologies and development pathways was hosted by Aalborg University, University of Groningen, and Stavanger University. The focus of this team was to analyse different technological options for the future energy system, including integrated biorefinery and CCU options (including in existing petrochemical complexes), techno-economic performance, and learning curves of advanced renewable energy technologies deep industrial energy improvement and waste heat utilisation of energy-intensive industries. The individual PhD projects had the following aims:

- Assessment of **HTL-biorefineries** with carbon capture for advanced **biofuels production**. (ESR6)
- The project aims to understand the **long-term technological** prospects of advanced **offshore renewable energy technologies**. (ESR7)
- Development of a real-time **optimisation** solution for **dispatchable energy supply** units. (ESR9)

This work package share their collaborations experiences with the **secondment partners** and the **ENSYSTRA project**. Eliana Lozano (ESR6) shared her experiences with the Goodfuels and COWI secondment partners: “In both companies I developed my research topics while interacting with the team, participating in meetings and exchanging knowledge related with the project that contributed to broaden the perspective I have of my research project in connection with the energy transition with a view on the market. At Goodfuels, I developed a case study about advanced biofuels production in The Netherlands that resulted in a journal publication, and at COWI I worked on a similar project for the Danish context. These experiences allowed me to identify similarities, opportunities and barriers for advanced biofuels in the two contexts and contributed to my understanding of the problem from a different perspective” (ESR6). Similarly, Srinivasan Santhakumar (ESR7) worked with ORE Catapult in the UK and the Shell Global Solutions International B.V in the Netherlands: “At ORE Catapult, I worked with Analysis & Insights Team to develop cost models for offshore wind technology. We had several

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discussions on investigating the results and its implications for technology's future. The final results have been written as a scientific publication, which is under review currently. I worked remotely with the New Energies team of Shell. During the secondment period, I estimated the long-term cost reduction potential for offshore wind technology. The work is currently submitted as a scientific publication. Exposure to different specialist teams within the company helped in gaining insights on technology (ESR7)".

Experience in **collaborating in an ENSYSTRA deliverable** was shared by Srinivasan Santhakumar (ESR7): "I had the opportunity to write the **brief policy deliverable** with ESR 1, 3, 10 and 13. The process of realising the policy brief went well. All of us had the opportunity to understand others' research work and had several fruitful discussions. The inputs from the supervisors and coordinators also helped us to be more concise about our context of the policy brief and deliver a good outcome" (ESR7).

- **ACTOR BEHAVIOUR AND INTERACTIONS (Work package 3)**

The team researching Actors Behaviour and Interactions was hosted in the University of Aalborg and the Chalmers University of Technology. The purpose as a team was to understand the drivers for energy system transitions through human behaviour and interactions, including socio-technical cultures, participatory processes, and market behaviour. Individually their purposes were:

- To understand the **energy cultures** and the influences of **disciplinary thinking** on knowledge input for the energy transition. (ESR10)
- To advance the understanding of which **ownership characteristics and models** could best promote onshore wind farms and district heating systems in renewable smart energy systems, and reduce related energy costs and prices. (ESR11)
- Build up an agent-based model to simulate the **investment decisions of power companies**, and analyse the transition to the low-carbon power system ESR12:

Their experience with collaboration was a result of a non-linear process. For instance, the matrix plan for collaboration realised at the beginning of the project had a motivational effect. However, collaborations were mainly influenced by other causes (relationship developed with partners, time spent discussing how to collaborate etc). The **partnership in the WP3** integrated perspectives to understand actors' behaviour. The collaboration had the participation of Jaqueline de Godoy (ESR10), Leire Gorroño-Albizu (ESR11), Jinxi Yang (ESR12), supervised by Professor Kathrin Otrell-Cass. Their

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process includes producing an annotated bibliography on the topic Actor Behaviour and Interactions in the Context of Sustainable Energy Transitions. Leire Gorroño-Albizu (ESR11) explains that "the document collects some of the key literature within the research field of the three ESRs. The purpose was to build a fundamental understanding of each other's research projects to discuss opportunities for collaboration. This second step was taken using a co-generation dialogue technique, applied with the guidance of the WP leader. The main outcomes of the co-generative dialogue session are being documented in a scientific paper. The improved understanding of each other's research areas led to more enriching discussions during consortium and WP3 meetings as well as to the research collaborations described below" (ESR11). Jaqueline de Godoy (ESR10) highlights that the article "explores the challenges of interdisciplinarity in energy research for early research scholars that must deal with the dichotomy of being in disciplinary departments and an interdisciplinary project" (ESR10).

Furthermore, an **interdisciplinary collaboration** was realised by ESR 10 and ESR 11. The first one explored the **institutional conditions for district heating companies' trustworthy behaviour**: "ESR11 led the study, the two ESRs collaborated to define the overarching research goals and aims, and to develop a suitable theoretical framework and methodology. Both ESRs participated in the data collection. ESR11 conducted the data analysis and wrote the first draft, and ESR10 reviewed and edited the draft. ESR11 contributed with knowledge on institutional frameworks, district heating systems and renewable smart energy systems and ESR10 contributed with knowledge on trust and culture. In the beginning, it was necessary to have several discussions to understand how to combine the two fields of expertise and use them to define the research idea and the theoretical framework. However, the initial challenge of combining the two fields was overcome and led to a well-conceptualised research idea and theoretical framework. The collaboration resulted in higher quality research outputs than what the individual work would have enabled. The scientific paper that documents the study is currently under review and will likely be published soon.

Furthermore, the collaborative work led to another research idea described below by Leire Gorroño-Albizu (ESR11). The second phase of the project explores the **experts' views on how to enhance consumers' trust in district heating**. The study is being led by ESR10. "The study builds on the data set collected for the previous study. ESR10 conducted the data analysis and wrote the first draft of the paper, with reviewing and editing by ESR11. Again, ESR10 contributes knowledge on trust and culture and ESR11 with knowledge on institutional frameworks, district heating systems, and renewable smart energy systems. However, the research questions and the theoretical framework are different in this study. Once more, combining the two fields of expertise becomes very enriching for the researchers

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and the research. Besides, I have the impression that having overcome the initial/fundamental understanding challenges, the collaboration is much more agile now" (ESR11).

- **POLICY AND MARKET DESIGN (Work package 4)**

The team researching Policy and Market Design was hosted at the University of Stavanger and the University of Edinburgh. The purpose of a team was to understand the role of governance structures, including policy, regulation, and markets, supporting the technological developments needed for a successful energy transition and regulating the interactions between actors playing a role in that transition. Individually their purposes were:

- **Market Design** to support Energy Transitions (ESR13)
- To examine the **role of politics and policy in energy system transitions,** particularly in the case of cross-border cooperation (ESR14)
- Explore the **role of the oil and gas industry** in the North Sea energy transition (ESR15)

Throughout the project, they have **worked as a team** on some tasks and projects in WP4. WP4 has had had to generate a great deal of work, and we have developed a good working professional relationship. "The overarching goal of ENSYSTRA is to facilitate collaboration amongst ESRs, with this in mind, the result reached, whilst not being directly expected (initially direct collaboration through article authorship was expected), has resulted in a networking being built amongst ourselves that will have great utility in the future"(ESR14).

In general, most of the WP experiences were related to the ENSYSTRA project deliverables. Benjamin Silvester (ESR14), together with Christian Fleischer (ESR5), Andrew Kilmartin (ESR13), and my supervisor Oluf Langhelle, first-authored a policy brief on interconnector expansion in the North Sea Region. He reflects that "initially it took some time to formulate a plan and to consider the best way to approach the policy brief deliverable however, at the end of the project the results were good and the expected outcome reached – a professional-looking, informative brief on an interesting and highly relevant topic to all of our collective research"(ESR14).

Furthermore, collaboration was carrier on for the **quantified scenario roadmap**, involving Benjamin Silvester (ESR14), Abhinav Bhaskar (ESR8), and the supervisors Oluf Langhelle and Mohsen Assdi. This was a substantial task and required a lot of collaboration from the WP1 that were the authors of the scenarios (Laura Gusatu, Rafael Martinez Gordon, Christian Fleischer, Maruf Nasimul Islam, and

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Xiaoming Kan). First of all, they develop a framework to get feedback in a structured format to ensure the roadmap was uniform and met the deliverable goal (ESR15).

Another experience shared was from Andrew Kilmartin (ESR13) with the **policy brief deliverable.** Andrew was the ESR point of contact/ facilitator or coordinator. "I was asked to lead on Policy brief lecture/training, and WP4 was nominated to help deliver the discussions and deliverables. In addition, I was directly involved in supporting and contributing to the following policy briefs: Policy Brief: #3 Opportunities and Barriers to Interconnector expansion in NSR Led by WP 4 (ESR14); Policy brief #2: Opportunities for an efficient future North Sea Energy System led by WP2 (ESR7); Policy Brief #6: From NOWnership to Ownership (define & promote local and inclusive ownership) led by WP3 (ESR11). Also attended two Industrial meetings to present Policy Briefs to Industry and input to discussions and helped with minutes and capturing salient points (as required by Ensystra deliverable) led by WP 1 ESR 4 and WP4 ESR 15" (ESR13).

ii. Theoretical understanding and levels of collaboration

To assess the understanding the ESRs gained about collaboration practices, we asked the following question:

Please see the diagram below where it is defined the degree of collaboration between disciplines.

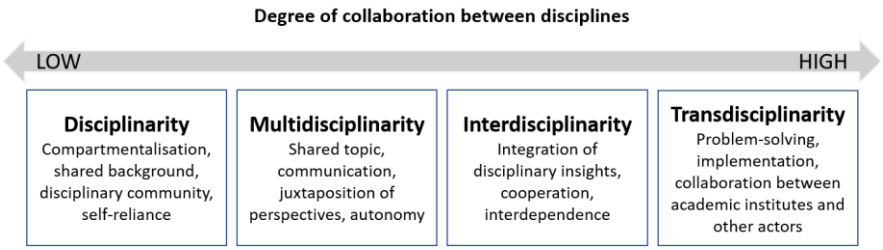

Figure 1. Collaborative research between disciplines. Source: (Wernli & Darbellay, 2016)

Based on those definitions, could you describe which insights from other energy research areas you have juxtaposed, aggregated, or created to answer your PhD research questions?

Disciplinary accounts happen on projects where the focus was on **renewable energy system modelling**, concentrating on **sector coupling and flexibility options**, thus the ESR secondments and interactions with colleagues and experts were primarily in the energy system modelling field (ESR2).

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- **Traditional means of producing energy (oil and gas industry)**: insights from the development of oil and gas industry were relevant in formulating scenarios for the use of offshore space. Aspects related to the lifecycle of offshore oil and gas infrastructure, reuse of infrastructure, and reserve depletion were inputs in the scenarios formulated for the first scientific article (ESR4).
- Inputs and suggestions provided by fellow ESRs and professors in the summer schools and workshops opened up conversations about other disciplines (ESR7).
- Most of the contributions from other energy research area which as helped me with my research questions has been primarily been disciplinary. As most of my work has been focused on modelling technologies and understanding their integrations within the energy systems I have had the opportunity to interact regularly with experts and peers in energy system modelling field both in and outside of the ENSYSTRA network (ESR5).
- I collaborated with researchers of my research group to review citizen ownership of wind turbines and district heating systems in Denmark (ESR11).

Multidisciplinary experiences:

- In the energy system modelling tool that I developed I included **multiple insights coming from social scientist and policy analysts, such as spatial constraints, synergies between activities, or laws and regulations.** Those aspects are usually undervalued in purely techno-economic analyses (ESR1).
- I have been able to use insights from other disciplines in my research project. These insights helped me understand and select the state-of-the-art technologies and their overall roles in the energy transition, which I later selected as components in my energy system model. For example, the learnings from ESR 6 and ESR 8 helped me understand more about **biomass and hydrogen technologies**, which I later utilised to **model biomass-based CHP and Hydrogen storage components in my energy models**. In addition, the learnings from ESR 14 helped me understand cross-border cooperation, which is an essential element of the interconnected energy system models of the future (ESR2).
- I do gain **insights regarding the social acceptance and different ownership models** in the energy sector (ESR3).
- "One example is the insights provided by ESR 4 on the use of **spatial planning to define availability of areas for energy related technologies**. The spatial planning method used involved the possible shared uses of **offshore areas by better understanding the needs of the actors** that use the same area. In part I was able to integrate these insights into my own work" (ESR5).

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- "I gained a broader perspective from a multidisciplinary collaboration and communication with other ESRs and their own research topics. My research questions are focused on the **technical aspects of technology development**, nevertheless, I feel more prepared to discuss the results in a broader context **incorporating** other elements of the energy transition such as **policies and social impact**" (ESR6).

Interdisciplinary experiences:

- ESR4 research consider **techno-economic criteria;** in determining the spatial constraints and opportunities in the allocation of offshore space for offshore wind farms, the cost of offshore wind farms deployment but also maintenance and operation, are essential. In quantifying and classifying the available space in different space allocation scenarios, I considered the foundation type in relation to different water depths, as well as the overall system costs (and more specifically the distance to shore) related to transportation costs. Data exchange regarding techno-economic factors influencing the location of offshore wind farms have been realised in collaboration with ESR 7 (ESR4).
- The two papers on district heating are based on interdisciplinary collaboration, as they integrated interdisciplinary insights (socio-technical energy systems and cultural psychology) and demanded collaboration and interdependence between the authors (ESR11).
- A general insight, which I have found has directly **impacted my research and view of energy issues**, is both an appreciation of the **utility of energy system models and also an acknowledgement of their weaknesses**. I would say this sits between the multidisplinarity and interdisciplinary boundaries, but I view it more as a methodological distinction – **different methods and approaches looking to find out related forms of information; what components and interactions are required for a sustainable transition and how to reach low-carbon solutions** (ESR14).
- I combined theories from different disciplines to answer my research questions. These included sustainable transitions literature and strategic management literature, as well as sustainable transitions literature and innovation intermediaries literature. The latter also had an element of multidisciplinarity as both fields had examined a shared topic before, albeit previously independently. Furthermore, during the secondments and ENSYSTRA training events and secondments, I was able to engage and gain experience from different disciplines, both academic and industrial, which has allowed me to reflect and challenge some of the underlying assumptions and narratives in the research field (ESR15).

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Transdisciplinary experiences were related to the secondment and exchange ESRs had the opportunity to engage on different interest groups and conferences beyond ENSYSTRA DAAG and SDP/SDG groups, INFORMS ENRE and DAS joined research efforts, for example (ESR13).

iii. Motivations, challenges, and learning outcomes

The following question was asked: **What were your motivations, challenges, and learning experience of collaborating in energy research projects?**

One prime **motivation for collaborating** in energy research projects is the interdisciplinary **nature of the process**, which results in a more **holistic approach** to the energy transition problem. This leads to a better understanding of the different **driving forces influencing or impeding the advancement of renewable energy development** (ESR4). Furthermore, collaboration allows understanding the **critical challenges of the complex energy transition** process from different disciplinary and interdisciplinary viewpoints (ESR2). This further allows **"generic approaches for optimum management of energy systems** using the real-time capability of artificial intelligence-based solutions, in terms of energy, economy, and the environment. Future energy systems that seek to **maximise energy utilisation, grid reliability, and resilience** while meeting the expected demand-side requirements must consider all available energy sources, including intermittent renewables, storage systems, and dispatchable energy units. The research results can reveal an understanding of the real-time optimisation of the future integrated energy systems" (ESR9).

Another relevant aspect that motivates collaboration is the opportunity to gain **feedback and maximise** the use of resources available to progress the science in energy research (ESR5) and learn from the colleagues and potentially improve the quality of the research outcomes collectively (ESR7).

However, there are still many **bottlenecks encountered** during collaborative work, mainly related to the **different language** used by each research field and knowledge gaps (ESR4) and the need to align **research questions** (ESR1). This requires that all **actors involved can be benefited from this collaboration**, and this resulted in challenges, especially when involving **different universities**, **timelines** (ESR2) (ESR4) (ESR7), **deadlines and research objectives** (ESR1).

Collaborating as early stage research is a complex task that "overlaps with the workload resulting from the PhD thesis, the university requirements, and the ENSYSTRA deliverables. Such tasks were consuming most of the research time. Therefore extra collaborations were not possible" (ESR1). Furthermore, aligning specific research objectives with other people's research, given the limited time

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and the different time frames between projects, requires expertise (ESR6). The availability of time has been a critical challenge; most researchers are working on separate projects and have a limited amount of time available to **collaborate with other researchers that are not working on the same project as them**. In addition, the current rules of the PhD program at my host institution do **incentives individual/single-author publication,** which does not foster collaboration with other researchers (ESR5).

In this way, the collaborative work was always seen as **something secondary**, which was understandable, even though it could save time and improve the quality of the outcomes (ESR7). For instance, to investigate the **integration of energy systems**, which involve various energy supply technologies and storage units (ESR9), varied backgrounds are needed. In some cases, preconceived ideas of how the research should be designed and conducted occur (ESR13), making it complicated to inform others on, e.g. the importance of politics and policy. Naturally, proponents of certain disciplines, theories, and methodologies advocate for their particular view(s). For example, engineers tend to be very focused on technical and economic components. In comparison, social scientists are more interested in interactions within living systems, and thus the human-based details of transitions (ESR14).

Recognising and dealing with different ontologies and epistemologies require expertise for fruitful collaborative experiences as people come from different environments and view the world differently (ESR14). In the end, the main challenge were finding a shared topic that fits within the research interest of multiple authors. The second challenge was collaborative working between different institutional environments with differing norms and standards with PhD research (ESR15).

Collaborative working with energy transition researchers from different disciplines has been a great learning experience. ESRs relate this allows to **understand transition problems not only from technical viewpoints but also from and market perspectives, as well as from social and policy ones.** Bringing together other disciplines to work together towards a common goal is a challenging task that requires a coherent and straightforward strategy to obtain the expected results. This approach is nevertheless highly valued when dealing with a complex process such as the energy transition, the **scientific knowledge** of different energy-related fields has been greatly **enhanced as a result of taking part in this project**, as well as skills related to **interdisciplinary collaborations**, such as **disseminating disciplinary insights to an interdisciplinary audience** and identifying relevant links between the different involved research fields (ESR4).

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Furthermore, having access to experts in these different fields has broadened my understanding of the aspects that **influence and drive the energy transition** (ESR5), such as those related to energy policy, innovation, and project management (ESR9). Another plus is the interaction and contact with talent within **each WP**, the interactions with colleagues contributed to **gain some understanding of other disciplines** during the PhD (ESR7). C**ollaboration and open-mindedness,** and issue realisation helped to review research design and refine research questions. It also **clarified practical points of collaborating at the front end of a project and then provided the means to achieve this.** Admittedly it shifted the research focus somewhat or alternatively helped justify model selection and application, "but I feel more confident in what I need to do based on patience and observation. One particular advantage to get to this point was the openness for all ESRs to share design, data and approach" (ESR13).

ESRs shared that there might be a need to explain even the most basic ideas and concepts when collaborating. It is necessary to ask questions whenever needed and use some time to read some of the relevant literature in the other researchers' fields—it will accelerate the process of mutual understanding. **Researchers who engage in interdisciplinary collaborations take two simultaneous roles** (i.e. the expert and the beginner). Thus, it is essential to be **aware of, and comfortable** with, this situation (ESR11).

The reward of collaboration in energy research projects was understanding the perspectives and theoretical backgrounds of other researchers. Doing this has been a major asset for energy research contributing to understanding key processes that drive and hinder the energy transition in different contexts (ESR15). Of course, all of this happens over time and through constant interactions, but appreciation for different perspectives can be gained, and a better understanding of techno/economic/political/societal interactions within systems can be viewed as all important determinants of energy system transitions (ESR14).

b. Organisational aspects: Host university, secondments and the project structure

We evaluated how the environment in which the ESRs were immersed contributed to the collaborative practices described above. In this regard, we took account of the practices linked to the host university

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research group, within the secondments partners and the facilities provided by the ENSYSTRA structure.

i. Experiences in the research group at the host institutions

We have asked the ESRs the following question:

> ***Concerning your host institution research group, which practices had favoured the collaboration on energy research? In case you have none, could you describe the practices of your research group?*** (Questionnaire question number 4)

The environment for collaboration practices in the host institutions reported by the ESRs had similar characteristics: regular meetings, seminars, supervision meetings, and training opportunities. Among the benefits reported are the opportunities to have guidance, assistance on the development of the PhD (e.g. from the Aalborg University), and feedback and inputs from experts. For example, the "University of Groningen organises very **regularly different department meetings** and PhD meetings where researchers from different disciplines present their research and get direct feedback and inputs" (ESR1). Similarly, the Europa-Universität Flensburg (EUF) had "**weekly research group** meetings where the exchange of ideas and regular feedback occurred and the ESRs shared insights about the development of activities in the ENSYSTRA project" (ESR2; ESR5). Strategies for promoting collaboration exist in the University of Aalborg and Chalmers University of Technology, like the **creation of spaces for internal and external exchange** of ideas, for example: "we have **regular lunch seminars**, where everyone take turns to present their research and participants ask questions about presenter's presentation. I think this contributes to collaboration because by listening to other's research work, you can potentially come up with some collaboration ideas" (ESR 12).

ESRs also have the opportunity to navigate and engage in various **national and international research projects;** experience that is relevant for acquiring research skill to Md Nasimul Islam Maruf (ESR2) that is immersed in the Center for Sustainable Energy Systems (ZNES) research group at EUF (ESR2). Furthermore, some ESRs have been exposed to **more than one department** at the host university. For example, ESR4, was involved in the Faculty of Spatial Sciences and the Faculty of Science and Engineering. There she "could experience different practices of collaboration. Among the host university ENSYSTRA group, based at the Faculty of Science and Engineering, the collaboration was

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most fruitful during meetings in person, when the **exchange of ideas**, data and information **with 2 ESRs** took place in a fast and organised manner".

On the other hand, in the Faculty of Spatial Sciences, the interaction took place both in-person and online **through fixed meetings**. The discussions focused mainly on the PhD progress, during **supervision meetings**" (ESR4). Similarly, ESR 10 started the PhD in the Learning and Philosophy department: "there I was **exposed to several activities** related to social sciences, humanities and cultural psychology. In the middle of my PhD, I moved to the Department of Energy Technology, where the activities running online due to the corona emergency were related to energy technology development and methods, which is an important part of my PhD (socio-technical energy cultures). I strongly **collaborate with my supervisor and co-supervisor**, exploring socio-technical and education problems of energy research. In my host university, I had **informal exchanges** of insights relevant to my thesis with the colleagues of my department"(ESR10). Another example come from the University of Edinburgh that has "networks developed with universities beyond ENSYSTRA cohort which allowed us to collaborate beyond ENSYSTRA which was very beneficial to ensure our research was unique and to drum up support and interest beyond ENSYSTRA" (ESR13). Also, from the University of Stavanger, the learning experience there has been enhanced with regular meetings and having a hierarchy of equal input has resulted in all members freely engaging and contributing ideas and solutions to research issues (ESR14).

The host universities also provide **training opportunities** for the ESRs. For example, on the Center for Sustainable Energy Systems (ZNES) from the Europe University of Flensburg's **yearly strategy week** "allow to participate in training and interactive sessions relevant to the group's research projects according to Md Nasimul Islam Maruf (ESR2)". To Christian Fleischer, (ESR5) such **annual retreats** organised by the group "allow for a more intense period of discussion on ongoing projects and possible new project acquisition" (ESR5). Similar training experience happens in the Chalmers University of Technology and in the Aalborg University. Xiaoming Kan (ESR3) experience in the Chalmers with the **regular seminars and workshops** allowed "to understand the most recent developments in the fields and to share ideas. We have a diversified team composition, where the members in the team can compensate the expertise of each other" (ESR3). Despite COVID-19, universities made an effort to keep providing an environment for collaboration. For example, the University of Edinburgh "had a series of Energy Systems Modelling and more recently hosted the INFORMS ENRE lectures, which brings together the key researchers in Energy Modelling fields. In addition, we are invited to Energy Policy research Group webinars, conferences, and seminars in all parts of the world. To understand

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and participate in Energy Transition workshops, seminars and webinars, i.e. Energy System Modelling focus groups, Weekly Mathematical Programming and Data Analytics, Weekly Supervisory meeting with various PhD and MSc members. More recently, weekly IET Seminars, Annual PGR Conferences and IAD Doctorate Training and support" (ESR13).

ESR9, Qian Zhang, highlight the **research facilities** provided by the research group at the University of Stavanger. "The group has access to state-of-the-art research facilities, such as highly fuel flexible micro gas turbine test rig, shallow geothermal energy reservoir connected to an advanced supercritical CO2 heat pump laboratory, and local industrial plants and energy systems. These are used for development and validation of tools and methods, physical and artificial intelligence-based models, which are used in integrated design, control, and optimisation algorithms" (ESR9).

ESRs also gained knowledge in **outreach communications due to participation in events, conferences, seminars. Elina Lozano said that she was an** "active participation in conferences and events particularly in the field of bioenergy" (ESR6). In Srinivasan Santhakumar (ESR7) host **institution (EUF), "colloquiums and seminars** are conducted frequently, where each staff member presents their research. Similar events have helped me exchange ideas and also get feedback on my work. Co-authoring the paper with other PhD students are appreciated in my host university, and the university allows to account the paper in each PhD student's individual thesis" (ESR7). Although the university environment can recommend potential collaboration, the ESRs conciliate all the collaboration opportunities is challenging for several reasons (ESR12).

Although the experience of being in contact with several **research projects** and **other research groups** can add value to young researchers (such as the experience of Eliana Lozano (ESR6) at the Energy Technology Department at the Aalborg University), it requires the ESRs learn how to prioritise the collaborations and activities with the ENSYSTRA, since that the involvement of ESRs in other research projects is limited to the ENSYSTRA project. For instance, Andrew Kilmartin (ESR13) reinforce other ESRs experiences, "while we were mainly encouraged to collaborate on tangible deliverables within ENSYSTRA, at The University of Edinburgh Institute of Energy Systems, we had ample opportunity for informal participation in several special interest groups, the department already had an excellent research group and experience of modelling and strategic understanding of the tasks at hand. In addition, through my supervisor's networks, we were naturally integrated into the department of mathematics, which helped with the Programming and Modelling approach and differences" (ESR13).

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ii. Experiences in the secondments partners

Regarding the experiences the ESRs had with the secondment partners, we asked the following question: **Related to inter-sectoral experiences, could you describe your secondments experiences? (e.g. did you participate in the organisation meetings, planned tasks together, or had a writing project) (Questionnaire question number 5)**

In general, the ESRs reported a facility to communicate with the stakeholder's partners on the planning phase of the secondments. For example, "with Chalmers University, the **communication** and alignment were straightforward" (ESR1). With TNO, even they were not an official partner of my research, the **communication** was very efficient, and their expertise and advice were beneficial for my research. (ESR1). The **planning phase** demonstrate an essential aspect for the **success** of Eliana Lozano (ESR6) secondments experience: "In both secondments (Goodfuels, COWI), I had meetings prior to starting in the companies to agree on the objectives and have a rough planning on the activities" (ESR6).

Christian Fleischer (ESR5) shared his inter-sectoral experience, that was with Statkraft Norway, and conducted virtually: "During the secondment, I worked intensively with two departments where the contents of the internship were discussed and agreed upon prior to the start of the secondment and continuously updated during weekly meetings with the department staff. The experience did give me an overview of how these large companies operate and how departments organise their work to get the best result" (ESR5). Another fruitful collaboration with stakeholders was reported by Andrew Kilmartin (ESR13): "In addition local Modelling interest groups and training in inter-sectoral approaches and challenges Gas, Electricity, Heat, Transport and Energy Transition efforts and CCS pilot schemes, Research and Development groups have been contacted and engaged including the DNV Energy Transition Outlook Modelling, Equinor Market Analysis groups. NTNU Mathematical Programming and Complementarity Modelling in Energy Market Design, Chalmers Energy Modelling from Industrial to Global level, DTU Advanced Optimisation and Game Theory for Energy Systems and DIW Berlin Energy Markets and Set Nav Project, Conferences and Workshops Energy Transition, Nordic Edge SMART City workshops (DSM) and attendance at Energy Transition workshops and seminars led by leading industrial partners: SSE/Equinor/Lyse and DNV have been contacted and discussions initiated regarding our research efforts." (ESR13)

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Some ESRs reported difficulties with the secondment partners scheduled for their PhDs, for example, some partners were **not very communicative**, and their research interests were not aligned with the **objective of my thesis.** However, others ESRs with complimentary secondments are still ongoing (e.g. ESR13).

During the secondment, the experiences of the ESR were at times more independent and very intense. For example, "my specific work **was mostly independent** however, I was in constant communication with people at the companies, I was invited to meetings within the organisation and had active participation in some of the meetings", says Eliana Lozano (ESR6). "The experience with the secondment with ORE Catapult was with **monthly team meetings** allowing us to understand what kind of the organisation is working on" (ESR7). Similarly, Jinxi Yang (ESR12) participated in the **research group's weekly meeting**, where everyone updates their progress on their research, she also participates in some of their seminars and talked with some researchers who work there. Her experience has fully online due to the COVID-19 situation, like the experience of ESR7 with Shell. At NAM, Harry Moncreiff (ESR15) attended **weekly meetings** where "progress on various energy transition projects were discussed including the **challenges and barriers they faced**. These challenges included technicalities but also challenges relating to the policy and multi-actor environment. During these meetings, I was able to contribute by asking questions and offering potential insights and solutions. For my research conducted at the secondment partner, I drew from different theoretical backgrounds and my previous research in other countries to offer alternative perspectives on the transition process. Overall my experience was invaluable with regards to how industry approach the energy transition, which I would not have been able to achieve the depth of insights through other means" (ESR15).

Other ESRs also had in-loco experiences in the secondment partners, Jaqueline de Godoy (ESR10) was in the University of Stavanger, the Chalmers University of Technology and the University of Groningen, studying the **energy culture that the ESRs** are **immersed in** when producing research on energy technologies and those of methods for energy modelling. In the same ethnography project, Jaqueline went to the secondment at Lysa, where she was **exposed to energy markets and innovation projects in smart technologies**. She evaluated: "Such fields provided me knowledge on the international and political challenges of energy markets. Furthermore, I was exposed to the challenges the company has to accommodate society wishes. The applied ethnography methods fit perfectly to extract the challenges the employees of the innovation team has on serving the community they are placed. Furthermore, the complementary approach with interviews helped assess their relationship with the

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environment they are surrounded to contribute to the research field of deep ecology to understand the challenges of Anthropocene" (ESR10).

The benefits perceived for the ESRs of the interaction with secondment partners were shared. Jaqueline de Godoy (ESR10) said that during her secondment at the Graz, she had many **knowledge exchanges with experts about education, digitalisation and technology and humans interactions**. She participated in a PhD course entitled Human Factor of Digital Technologies, where she gave a talk about surveillance capitalism practices in the energy sector and a group talk about the value of privacy when it comes to data collection. Benjamin Silvester had his experience at the school of engineering at the University of Edinburgh. In his own words; "it allowed me to step away from my host institutions and observe and work in a different environment, which was itself an important research experience" (Benjamin Silvester - ESR14). Similarly, other ESRs reported that the host secondments offered the opportunity to meet different stakeholders, get involved in insightful discussions that helped clarify how to define and investigate the PhD research questions, and acquire research data when possible.

Some of the reported **research outcomes of the secondments experiences** are a research article from Rafael Martinez Gordon (ESR1) in collaboration with TNO analysing the role of spatial resolution in energy system models published in Renewable and Sustainable Energy Reviews in March 2021. Two forthcoming articles that Xiaoming Kan (ESR3) produced due to the regular meetings with researchers in Flensburg University. A scientific publication where two co-authors are secondment experts from ORE Catapult and Shell (ESR7). Ethnographic data collected at Lysa AS and the academic partners (RUG, GU and UiS) are part of two articles in the process by Jaqueline de Godoy (ESR10).

Furthermore, in a detailed deposition about the secondment, Laura Gusatu said that she took part in several meetings and the other 2 ESRs placed at Europa-Universitat Flensburg (EUF). The meetings served as platforms for discussing our projects/the research plan and establishing objectives for the research visit. The secondment helped establish a **network of industry experts**, which contributed to **the data collection (interviews) for the first paper**. The secondment was also beneficial as it offered the possibility to understand better the energy models developed at EUF. At the same time, it also facilitated the exchange of data, namely the spatial footprint of offshore activities for the energy model developed by ESR 5 (ESR4).

Furthermore, Laura´s secondment at the Institute of Marine Science – CNR Italy was very productive as it resulted in a published paper. It opened opportunities for future collaboration on a scientific paper. Along with the research team at the institute, **I coordinated and performed the data collection**

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and analysis while also participating in group meetings. During the secondment at ISMAR-CNR, I offered a presentation detailing the ENSYSTRA objectives and my current research conducted at the institute. By directly accessing the facilities available at the institute and interacting with the experts in data analysis and remote sensing, we were able to advance with the research at a good pace (ESR4).

iii. Support from the structure of the ENSYSTRA project

To account for the contributions the ENSYSTRA network had on the collaboration practices, we asked the following question: **How the ENSYSTRA project facilitate collaboration in your PhD research project? (Questionnaire question number 6.)**

"The positive outcomes reported concerning the **support for collaboration from the ENSYSTRA** project were related to workshops and encounters that allowed interactions and insights from experts from many energy-related fields. The ENSYSTRA project included multiple summer schools, seminars, workshops, and events where different sessions were explicitly dedicated to finding collaborations between different ESRs" (ESR1). "The ENSYSTRA network favoured **engagement at conferences, workshops, and webinars.** As a representative of the ENSYSTRA project, I had the opportunity to meet environmental and spatial planning researchers, as well as representatives of the offshore wind industry. Hence, during the Connecting Seas conference, I could interact with the developers of Tools4MSP, the geo-spatial analysis tool I used for my second paper" (ESR4). "Furthermore, the **events organised by the ENSYSTRA project** (ESR7), such as the workshops and summer schools, provide ESRs with the opportunity to meet and discuss research ideas. Also, with the project having a multi-disciplinary approach, ESRs from different disciplines can learn from each other and gain a more holistic understanding of the energy transition. This approach is not common in academia and presents the ESRs with the opportunity to look at research opportunities involving the collaboration of multiple disciplines" (ESR5).

"Such collaborative **research works and training activities** with other ESRs and experts helped me gain insights into the overall energy transition, which helped me design and develop my research project" (ESR2, ESR3)**. "With ENSYSTRA, ESRs could assess experts** in renewable energy, spatial analysis and environmental assessment. First, the guidance through the PhD process was offered by resourceful and experienced supervisors, who provided precise requirements and constant support. Second, the

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extended **network of my supervisors** was beneficial throughout the project by providing data and feedback on the research" (ESR4).

Another differential mentioned is the "**interdisciplinary objectives** also aimed at **establishing collaborations** within the research group, to solve complex problems addressing multiple disciplines" (ESR15, ESR14). "Interdisciplinary collaborations: Through the ENSYSTRA summer schools and workshops, the ESRs maintained a constant dialogue regarding various energy transition-related topics. Lastly, based on the identified synergies, I will be collaborating for a joint scientific paper with two of my colleagues from the Work Package 1 and 2" (ESR4). "In this regard, the ENSYSTRA project has been a great networking and learning experience because it allowed me to expand my knowledge in the energy field beyond my research. From the project, mainly initially, there was a lot of motivation to collaborate with other PhDs however, I think it is difficult to reach a high degree of collaboration in a normal PhD time frame" (ESR6). "WP4 experience had excellent guidance due to the work package leader interdisciplinary background, which contributed to guide their collaboration. The knowledge acquired was more about the challenges and way of collaborating in academia, which can be suitable for my future career" (ESR10, ESR12).

The built-in network ENSYSTRA has helped guide research through all of the **instructional seminars and lectures we have been given at various summer and winter schools and workshops**. In addition to this, learning more about my fellow ESRs research has been invaluable in appreciating the different ways of viewing and conceptualising energy system components and approaches" (ESR14). Furthermore, the **secondment opportunities** by the ENSYSTRA provided excellent on-the-job training, which improved my skills and helped me better understand the relation between theoretical and applied research (ESR2, ESR3, ESR7, ESR15).

Among the challenges of the ENSYSTRA for the ESRs were the difficulties in understanding how to approach tasks and the product or deliverable, because at times tasks on the ENSYSTRA project proposal were not sufficiently described or detailed (ESR13). Thus the agreement on how to undertake a task is often the first hurdle to any form of collaboration, so we have learned to take in advice, show initiative, most importantly, support and assist the leads on activities and provide the necessary/sufficient input balancing value and benefit. Interestingly, similar collaborative methods and techniques were applied across several deliverables, which exhibited "learning by doing" qualities and benefits realisation. What we need to do now is capture the lessons learned, or more specifically, quantify "what went right or what went wrong" so that any bad habits or sub-optimal practices can

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be removed, improvements communicated, so that future facilitation and collaboration is improved. This is more commonly known as a post-task “wash-up”, so feedback on the deliverable is key to this exercise. This has not happened to date but will be required for project closeout (ESR13). Furthermore, during many phases of the project, there was a conflict between each University interests and the ENSYSTRA suggested collaborations, and the high number of unexpected deliverables, university requirements and recurrent workload of a PhD complicated to collaborate with other ESRs in the long term effects.

4. DISCUSSION

a. Collaboration in Energy Research

In this section, we discuss from an interdisciplinary perspective the meaningful experiences that have been shared in the previous sections. Energy system modelling for the energy transition was a key tool used in the ENSYSTRA project to integrate and compare energy scenarios. For this, data sharing among and perspective from different experts fields alluded ESRs to generate innovative knowledge. Contextual analysis was performed to compare technological costs and their influence on spatial and economic components. Furthermore, it was explored the costs of the energy and the energy transition of green batteries, energy policies and sector coupling, and the advantages of investing in solar PV to meet the growing demand.

Cooperation regarding the new technologies and development pathways, ESRs reported cooperation experiences related to biofuel production, to the study of cost models for offshore wind technologies and the challenges and benefits of interconnectors in the North Sea region. Experiences of collaboration to understand actors behaviour and interactions rely on bringing the perspectives of different actors (industry, academia, and those related to ownership models) to build a fundamental understanding of the challenges and dichotomies of implementing changes in the energy sector. Furthermore, cooperation between socio and technical areas has also been reported since some ESRs work in science, technology, and society, which is by nature a field that requires interdisciplinary perspectives.

The role of policies and market design on the energy transition is a connection point where most areas could expand the analysis to that direction. For instance, when developing quantified scenario, roadmaps input from modelling was required. Similarly, ESRs under this research area explored the barriers for interconnectors, contribute to the analysis of ownership models and opportunities for the efficient North Sea.

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Among the motivations to collaborate, early-stage researchers visualise that the nature of the problems of an energy transition needs interdisciplinary knowledge and holistic views, thus they envision acquiring research profiles able to contribute to the advancement of the energy transition. They mentioned that interdisciplinary projects like the ENSYSTRA offer a great opportunity to gain feedback from several experts and maximise the progress of science in energy research.

However, bottlenecks exist to collaborate, experts use different language, and it is hard to align research questions because all the actors involved must benefit from the collaboration. This is complex because, as early-stage researchers, constraints of timelines, objectives, and views of the importance of interdisciplinary research exist. The incentive of institutions involved has been demonstrated to be fundamental for such

b. Organisational Accounts

The ESRs experiences that enhance interdisciplinary knowledge at the host university were enriched with regular meetings, colloquies and seminars, yearly training, informal exchanges, collaboration with supervisors, training opportunities like PhD courses, workshops, and teaching experiences. In addition, some ESRs had contact with more than one university department and national and international research projects. The intense training favoured the development of an integrated view about the energy research area and cross-disciplinary perspectives. Concerning the secondment partners, ESRs highlight straightforward communication with some partners, while some highlight a lack of alignment regarding the cooperation purpose. This lack of synchrony added constraints for the ESRs since they need to fit the secondment results with the thesis purpose. The planning phase was essential for the success of secondments, thus this may require more supervision considering the complexity the task entails (e.g. changing country, adapting to the industry environment and dealing with administrative added tasks). When expectations and purpose were aligned with the secondment partners, ESRs could engage in the organisations' departments, extract the data relevant to progress with the research and adopt different theoretical and methodological accounts considering the inter-sectoral views and contributions.

Undoubtedly the structure of the project grants a considerable impact on the ESRs career. The knowledge acquired with the experts from multidisciplinary fields, who contributed to conferences, workshops and events, in general, allowed ESRs develop a holistic understanding of the energy transition. In addition, the contribution of supervisors providing feedback on the research focus and

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development during the ENSYSTRA events contributed to add perspectives and enhance ESRs views about interdisciplinarity, such results are possible due to the interdisciplinary network accessible for early-stage researchers on the ENSYSTRA project. Furthermore, the secondments platform accessible to the ESRs was excellent to build bridges between academia and industry and between theoretical knowledge and practical applications and challenges. All of this requiring a short period for the ESRs regarding negotiating secondments opportunities due to the ENSYSTRA structure provided. However, other tasks add a lot of bureaucracy for the ESRs that could be smooth if a flatter structure takes place.

5. CONCLUSIONS AND RECOMMENDATIONS

General conclusions can be made out of the Energy System in Transition Project.

- Alignment of institutions (host university, research group, secondments and the project management) is the key for cooperation. Early-stage researchers should feel encounters of ideologies to pursue interdisciplinary profiles and knowledge.
- Senior experts effort to deal with interdisciplinary projects and bottlenecks that can emerge is the key to integrate disciplinary fields. This can require the senior experts to adopt a double role (as of seniors and learners) to cross-disciplinary boundaries.
- The time required for cooperation cannot be underestimated, thus, an initial plan should do in collaboration with the expert's team (e.g. supervisors of the respective ESRs).
- The willingness of actors involved with the ESRs project to cooperate and collaborate is the key to success, for example, the secondments for the ESRs should be aligned with the ESR thesis purpose. Thus, at times may be necessary to have more flexibility to make structural changes to the ESR project plan. An important point here is that the project was planned before knowing who will be the ESR`s developing the project. In this case, subjective characteristics should not be disregarded in the process.
- Alignment between supervisors and the ESRs about the purpose of the collaboration is mandatory. In another case, ESR could be discouraged to cooperate from the perspective of the host university or supervisors and encouraged to cooperate by the nature of the ENSYSTRA and Marie Curie Project (interdisciplinary training).

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APPENDIX

Section 1. QUESTIONNAIRE FOR THE ESRs

Personal and Project Information
ESR Name/Number:
Project Aim:
Host University:
Secondments Realised:
Methodological Accounts
1. At the beginning of the ENSYSTRA project, collaborative research projects were planned together with ENSYSTRA colleagues (e.g. matrix available on appendix 1 or through the work packages meetings), with the secondment partners and the host university research group. Based on your experience, could you relate at least three projects where you worked as a team describing the process to do so, the details of the project and results expected/reached?
2. Please see the diagram below where it is defined the degree of collaboration between disciplines. **Degree of collaboration between disciplines** LOW — HIGH **Disciplinarity** Compartmentalisation, shared background, disciplinary community, self-reliance **Multidisciplinarity** Shared topic, communication, juxtaposition of perspectives, autonomy **Interdisciplinarity** Integration of disciplinary insights, cooperation, interdependence **Transdisciplinarity** Problem-solving, implementation, collaboration between academic institutes and other actors Figure 1. Collaborative research between disciplines. Source: (Wernli & Darbellay, 2016) **Based on those definitions, could you describe which insights from other energy research areas you have juxtaposed, aggregated, or created to answer your PhD research questions?**
3. What were your motivations, challenges, and learning experience of collaborating in energy research projects?
Organisational Accounts
4. Concerning your host institution research group, which practices had favoured the collaboration on energy research? In case you have none, could you describe the practices of your research group?
5. Related to inter-sectoral experiences, could you describe your secondments experiences? (e.g. did you participate in the organisation meetings, planned task together, or had a writing project)
6. How the ENSYSTRA project facilitate collaboration in your PhD research project?

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