Reflection through Diffraction:
Interdisciplinarity in Energy Science

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ABSTRACT. 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.

Introduction

Solving today's complex sociotechnical problems, especially those trying to address responses to the climate crisis, requires that experts from interdisciplinary fields work together (Büscher et al., 2018). However, the underlying logic and purposes of disciplinary fields pose practical challenges when experts collaborate, especially when interdisciplinary insights are expected from researchers who are still at the beginning of their academic careers (Dooling et al., 2017). This article presents an account of three (out of fifteen) early-stage researchers (ESRs) who worked together in the Energy Systems in Transition (ENSYSTRA) project on sustainable energy transition (ENSYSTRA, 2018). Each ESR embarked on their independent doctoral research project eager to understand their own disciplinary footing while also being tasked to collaborate with each other. We focus specifically on interdisciplinarity as a concept (not transdisciplinarity or multi-disciplinarity, see also Osborne (2015) since interdisciplinarity was stated as an explicit intention by the ENSYSTRA project (ENSYSTRA, 2018).

Disciplinary collaborations are characterised by researchers tackling a problem from a common background to generate knowledge. While researchers may be occupying niches that may be signified with different preferences on methods or theoretical takes, disciplinary research stays typically within disciplinary boundaries and generally carries the intention to refine basic or fundamental knowledge (Van den Besselaar & Heimeriks, 2001). In contrast, there is an expectation that interdisciplinary collaborations draw insights from diverse disciplines that are being utilised to produce more application-focused knowledge (Wernli & Darbellay, 2016). However, the blending of different traditions and knowledge products is often hard to achieve, which is why such research arrangements are sometimes better described as being multidisciplinary. In multidisciplinary research settings, different disciplinary experts join to examine the same problem from their disciplinary angles, but they do not integrate each other's findings in contrast to interdisciplinary teams who create their own 'theoretical, conceptual and methodological identity' (Van den Besselaar & Heimeriks, 2001, p. 706).

Interdisciplinary research is increasingly asked for because of the complexity of the challenges late-modern societies face. However, teams consisting of different research traditions and research practices can give rise to tensions due to time requirements, divergence in professional interests and motivations (Verouden et al., 2016), as well as misunderstandings due to the disciplinary epistemological assumptions, and the ontology of production and organisation of knowledge (Fernandes & Philippi JR., 2017; Mansilla, 2006; Winskel, 2014). In addition, disciplinary research is often focused on producing outcomes of a more general nature, while, in interdisciplinarity research, the focus on application is essential since it requires different inputs to solve real-world problems that come with a high degree of complexity (Krohn, 2017).

Put into the context of sustainable energy transition research, such topics will arguably need to investigate the full spectrum of insights ranging from basic sciences to policy changes, economic processes, user studies, energy planning, as well as new formats of cleaner energy production, resources, and technologies (Tijssen, 1992). For interdisciplinary research to work, it will require the willingness to share insights and formats that allow for the integration of different viewpoints. It may also require the honesty to confess not knowing and openness to learn from each other. While sustainable energy solution research has been described being a prime example for conducting interdisciplinary research, this is still rare since the insights contributing to this field range from anthropology to psychology, computer science to various engineering disciplines (Schuitema & Sintov, 2017; Sovacool, 2014). An integration of knowledge from across those different fields requires that the challenges and barriers that such ambitions face are explicitly addressed. Failing to understand the different contexts of different expert fields is likely to result in failing to comprehend the complexity of the problems that researchers are trying to tackle (Schuitema & Sintov, 2017). It is important to note, however, that interdisciplinary knowledge should not replace expert understanding but rather add an additional layer of knowledge, and this will require that experts from different fields learn to listen to each other (Verouden et al., 2016). Although this may sound easy, it is far from common practice, also because it may position a knowledge expert from one field into the position of being a novice in another (see, for example, the comparison of performance between expert and novice in the context of teaching where teachers have a more structured knowledge centred in fundamental concepts, theories, and themes than novices (Niemi, 1997).

In an attempt to develop an interdisciplinary understanding of sustainable energy transition research, the following work presents the learning journey of three ESRs who attempt to understand what interdisciplinarity might mean in the context of their work and to show what specific insights were generated in the process. The accounts of the three ESRs are meant to be exemplary of the challenges and present a structured approach the three agreed on, and that gave space to reflect on one's disciplinary habitus. Scholars are susceptible to the faculty habitus of variations in research, funding, research agendas, timeliness, students' socialisation and development, as the individuals are greatly influenced by the faculty background and the prestige of the departments (Mendoza et al., 2012). In this way, we find that habitus, Pierre Bourdieu's (2008) research tool to reconstruct social structures, is a helpful thinking tool to understand individual dispositions and approaches to practice (p. 138).

However, the disciplinary reflection only may lack the understanding of how the habitus (that can be considered here as disciplinary boundaries) occurs when the aim is to understand the emergence of interdisciplinary cross-boundaries, for instance, to analyse the encounters between the ESRs. Bourdieu's concept of habitus highlights the conditions that shape embodied practices and the

interrelatedness of people's relationship to the environment that they inhabit. Habitus helps to unravel the motivations of individuals and the struggle they may experience that is related to the social fields they operate in. Although habitus provides the grounds for understanding social structures and allows to build pathways for changing discipline-centred cultures, the concept can be vague to identify interdisciplinary encounters. Here, we find that Donna Haraway's (1991; 2016) ideas on reflection and Karen Barad's (2007) notion of agential realism can offer a new type of vocabulary. They call for a re-imagination of the meaning of reflection and reflexivity. They critique the traditional assumption that we have direct access to the materials we work with and that we leave no impact on the objects of our inquiries. According to Haraway's and Barad's theories, if we encounter material practices in and with other disciplines, they will surely leave a trace. To be reflective, then, means to take note of the cuts that such encounters generate since they (the cuts) enable the new insights individuals experience. Barad writes that 'knowing does not come from standing at a distance and representing but rather from *a direct material engagement with the world*' (Barad, 2007, p. 49, emphasis given). Barad's (2007) concept of intra-action contests the traditional scientific ideal of objectivity through her focus back on the individual engaged in material practices who was previously believed to be neutral, impartial or somewhat invisible. Haraway explains that knowledge is always situated and embodied through practice. Situated knowledge is reflexive since it is 'the joining of partial views and halting voices' (Haraway, 1988, p. 590). It makes thus sense to us to apply these ideas to the research construction where early career researchers, who are still learning about their own disciplines, are 'halting their voices' and becoming self-conscious of their 'partial views.'

Trying to understand each other's disciplinary fields is a mode of collaboration that funding agencies increasingly demand to ensure that research is responding to the needs of society (Van den Besselaar & Heimeriks, 2001). We present a reflection on the agency of the ESRs when they are in the process of producing knowledge in the field of energy transition and aim to comprehend why some 'systems undergo change slower than others' (Kok et al., 2021, p. 462). We were also inspired by Sovacool et al.'s (2020) elaborations on sociotechnical perspectives, highlighting the inherent co-production of knowledge between 'energy systems and human affairs' (p. 3). We are interested in finding out about knowledge creation that aims to answer complex questions, especially when the limits and margins of nested fields are realised, considered, or challenged (Leiden et al., 2016; Stephenson, 2017).

While there is a 'persistence of significant obstacles at many levels of the creation of knowledge' (Leiden et al., 2016), we believe it is helpful to adopt an 'agential realist ontology' in order to 'open up a space for a new formulation of realism' (Barad, 2007, p. 207). In a realist formulation, 'mutual constitution of entangled agencies' is considered (Barad, 2007, p. 33) as a focus shift of humans as the only 'possible subject or object of study' to include underrepresented elements

and situate processes, knowledge, and the material context (Ulmer, 2017, p. 832). However, this requires that we open the black boxes of individual research fields and allow for encounters of different methods, processes, and practices so we can learn from each other. Furthermore, we reflect on the ontological nature of how the disciplinary methods we use limit the insights about the real world and rework 'the triad of things, knower, and knowledge, shifting the focus from questions of correspondence to practices of doing' (Barla, 2021, p. 11). Barla (2021) explains that it is about 'stepping out of the mirror' because the mirror reflects distortions and hides the true other, but that this can be overcome by using Barad's concept of diffraction as a method and phenomenon (p. 8).

Barad (2007) explains that we need to make agential (not Cartesian) cuts and that 'different agential cuts produce different phenomena' (p. 175). However, this is only possible if we adopt a methodological sensitivity towards our own attunements, and only then can we develop an understanding of the 'socio-material enactments that contribute to, and are part of, the phenomena we describe' (Barad, 2007, p. 26). Diffraction as a method for interdisciplinary research then means that we become sensitised towards our own agencies and touched by their meaning for our inquiries. The implications of these ideas are, for us, best exemplified through contextualisation. We will next set the scene by briefly explaining the situatedness of the research group to show the entanglements and challenges imposed by our intention to work as an interdisciplinary research team.

The Context: Interdisciplinarity in the Energy Systems in Transition Project (ENSYSTRA)

The group of 15 early-stage researchers (doctoral students) were part of the 'Energy Systems in Transition' (ENSYSTRA) project that unites academic and industrial institutions from six countries in the North Sea Region of Europe (ENSYSTRA, 2018). The project's intention was to support the doctoral students who all came from other countries than their research host country (a condition) and arrived with different research backgrounds and experiences. The project was organised to cover a range of topics all related to better understand the conditions and possibilities for sustainable energy transitions in the North Sea Region, intentionally drawing together disciplines ranging from natural sciences and engineering to humanities anthropology, politics, and economics, to generate new insights to model sustainable futures. To support that, the early-stage researcher (ESRs) had improved possibilities to study their fields and learn from each other the project included specifically designed ENSYSTRA project summer schools and workshops, extensive internships with industrial and academic partners, and a set of deliverables to be produced jointly to report on specific results. The project was organised into four main work packages: (1) Energy System Modelling, (2) New Technologies and Development Pathways, (3) Actor Behaviour and Interactions, and (4) Policy and Market Design.

PhD students who are working to develop their own professional self in their disciplines are rarely trained to work at the same time with other disciplines to solve complex problems, which demands 'skills and competencies that researchers are not used to' (Krohn, 2017, p. 3) or have not acquired yet. It requires that individuals, departments, and organisations commit to implementing strategies that balance individual disciplinary research with interdisciplinary interests and training for projects of this magnitude (Dooling et al., 2017). Entire books are devoted to interdisciplinary research, such as the *Oxford Handbook on Interdisciplinarity*, that attest to the significance and breadth of challenges (Frodeman, 2017). We argue here that it requires specific *pedagogical* steps to support the development of higher-order thinking, holistic views, and taking team approaches to solve contextual problems (e.g., the reflective method applied in a problem-based learning [PBL] [Fladkjær & Otrel-Cass, 2017]).

It can be said that for the success of sustainable energy transitions in a project like ENSYSTRA, it seems fundamental that the different stakeholders not only share their knowledge and products but take time to take in each other's understandings. It seems, therefore, important to find out how becoming experts, doctoral students, from different disciplines, see and interpret each other's ideas and insights. However, as Pellegrino and Musy (2017) write:

> 'Interdisciplinarity' is one of the most' fashionable' words to be found in contemporary energy research. The hype and the fuzziness that can characterise its use conceals a bright promise for research: the possibility of opening up new research perspectives, of finding new answers, but also of raising new questions.

The precise intention of the work presented here was to follow up on these thoughts.

Seeing Things Differently: The Research Questions

Interdisciplinarity is about making allowances to observe, do and interpret things differently. This means that interdisciplinarity is strongly connected to methodology and the ability to communicate the differences in the observations being made. Interpretations of observations are shaped by an observer's ontological and epistemological standpoint and can 'cement observers to their objects' and incorporate 'cultural habits of watchfulness and classification' (Daston & Lunbeck, 2011, p. 371). Observations foreground some aspects over others, and in fact, during the analysis process, some aspects are ignored completely. This approach should help in disciplinary research to simplify the overall complexity of the natural and human-made world and the societies within to interpret and unpack complex problems within this world.

Some disciplines are epistemologically interdisciplinary by nature, meaning that they 'accept cases in their complexity and contingency' (Krohn, 2017, p. 2) (as exemplified in the context of the humanities, for example, cultural studies and

psychoanalysis by Moran [2002]). In simple words, such disciplines focus often on real-world problems and are shaped by this dynamic of observing and creating theories to 'solve' such issues. Research concerned with climate change fits this definition. However, in projects like ENSYSTRA, interdisciplinarity also relies on 'how to relate knowledge about complex and singular cases with knowledge about generalised concepts and causalities' (Krohn, 2017, p. 1).

Energy research is often focused on finding technological solutions and applying positivist methodologies (Pellegrino & Musy, 2017). However, the ENSYSTRA project includes also research areas that are situated in the social sciences, and this can present a challenge to understand each other's approaches and possible insights. Interdisciplinary encounters require then the ability to reflect and question the meaning of who has authority over knowledge and what scientific objectivity actually entails (Barla, 2021). Therefore, the questions we ask ourselves here are as follows:

1. How can we orchestrate the conditions that assist us to think and learn together about our differences and situate one's own knowledge in an energy transition research project while locating new insights?
2. How can we practically facilitate a 'direct material engagement' to exchange ideas on how to examine the 'world'?

The methodology that helped us to solve these questions will be explained next.

Method to Facilitate and Evaluate our Material Engagement
Methodologically we have chosen to work with Karen Barad's (2007) 'diffractive methodological approach.' Barad uses diffraction in relation to interdisciplinary practices. For Barad, the traditional boundaries between the object and subject are not taken for granted. Rather, they are investigated as material-discursive phenomena and boundary-making practices, since this allows to 'inquire into the histories of the organisations of knowledge and their functions' (2007, p. 93). The methodology of diffraction also allows exploring a dynamic relationality. Recipients receive ideas differently, which Barad likens to the physics concept of diffraction, where waves that pass-through openings or obstructions and subsequently spread differently thereafter. Diffraction as a methodology means we can pay attention to differences and not necessarily seek sameness. In our attempt at interdisciplinary inquiry, the metaphor of diffraction enables us to search for the superposition of various 'waves' of knowledge (Barad, 2007).

Since three of the four authors of this article are ESRs in the ENSYSTRA project, we decided to examine our own thinking to explore 'interdisciplinary practices in conversation with one another' (Barad, 2007). Therefore, we focused on 'our' work package on energy cultures and agents' behaviour. Discipline-wise, we occupied the fields of energy planning (situated in engineering), techno-anthropology (situated in the humanities) and energy economics (situated in the social sciences).

Key to understanding the methodological approach for this article is that the authors are *both,* the research subjects as well as the researchers constructing the argument that is presented through reflection. The idea is that we wanted to resist the classical reproduction of understanding through a deliberate challenge of the traditional power-knowledge axis (see also Foucault [2000]). Or, as Kondrat puts it, we need to start with questions about 'the world'; to then review and reflect about our own world; before we can finally query the connections and contradictions between those worlds (Kondrat, 1999, p. 465). Taking an approach of professional self-reflection should allow us to get a sense of 'the nature of that role' that humans play (Barad, 2007, p. 151). Ethico-onto-epistemology interweaves practices of knowledge and practices of being. To assist with the messiness of this approach, we will guide the readers through this process (see figure 1).

Figure 1

Three phases of our material engagements
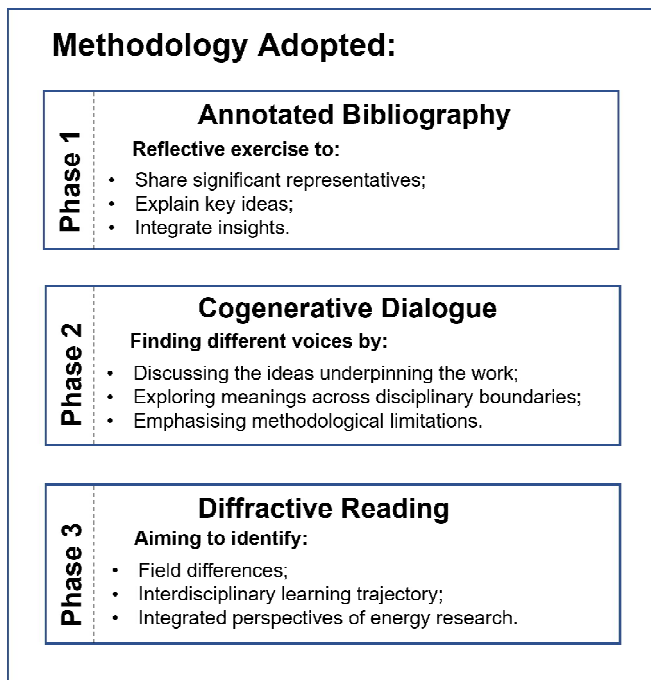
The production of an annotated bibliography characterises phase one (Godoy et al., 2020). On it, we cover diverse lenses of research related to behaviour in energy systems, where there is the assumption we have 'direct access' to the content we are representing (Barad, 2007, p. 381). Similar European projects, like the Shape Energy project, have produced bibliographic material where the inclusion of several disciplines was aimed to ensure the representations of diverse perspectives

on the fields of energy research (e.g., Heidenreich et al., 2017). We decided to produce a joint bibliography for several reasons: We wanted to share significant representatives and thinkers who had shaped our approaches up to that point in time of our research. Further, the literature was also selected with the aim to explain to each other what key ideas were relevant at the time in one's domain and why. Another aim of creating an annotated bibliography was so that we would be in the position to consider, read, try to understand and (where possible) integrate insights generated from each other's disciplinary area into our own work. This step has also been described as essential for interdisciplinary collaborations since disciplinary understanding in each other's fields needs to be developed first (Danermark, 2019). Another reason for going through this exercise was that we considered it to be a valuable source of information to gain more understanding of the individual PhD projects. Finally, we considered this to be part of our reflective exercise, a structured way to think about our own key theoretical influences and to get acquainted with each other's ontologies and their relevance for the energy transition in the North Sea region.

This methodological approach is deliberately subjective and is shaped by a number of biased factors, such as the researcher's preferences and values, future career goals, past experiences, or even preferred style, supervisor preferences and perhaps also one's network recommendations about key references, authors or methodologies. We are aware of this and want to highlight it, rather than hide it and pretend to be objective. The approach is also of temporal quality because it represents a snapshot in time of a person's thinking and development.

In a second step, we engaged in a cogenerative dialogue (Roth & Tobin, 2001) to discuss the ideas underpinning our work and explain to each other literature and ideas that seemed very important to us and reflect on our encounters. We use the method of cogenerative dialogue as an evaluation tool to explore meaning across disciplinary boundaries, challenge each other to step out of the comfort zone of our disciplinary background, and reflect on the challenges present in new and unusual concepts adjacent to our areas of interest. According to Fladkjær and Otrel-Cass (2017), one of the advantages of using a cogenerative dialogue format is that 'different voices can be positioned more prominently, not to share our anecdotal discernments but to showcase how we catalysed our thinking of a shared educational experience' (p. 84). Finally, in a third step, we utilised the cogenerative dialogue format based on each other's preparatory writing in the annotated bibliography with the intention to engage in Barad's methodological practice of diffractive reading, which implies 'insights through one another,' acts that are 'marked by patterns of difference' (Fladkjær & Otrel-Cass, 2017, pp. 25, 71).

Cogenerative Dialogue and Analysis
Following the process suggested by Roth and Tobin (2001) on how to set up, run and record a cogenerative dialogue, the authors, three early career researchers and one supervisor who had applied this dialogic approach before met online via video

conferencing. Prior to the meeting, the three ESRs had prepared their contribution to the annotated bibliography and shared their bibliographies with each other. The supervisor acted as a moderator. The conversation was organised in a way where each person explained to the others what key literature they had selected, why it was important to their focus of study, and to explain key concepts and ideas. This allowed the others to ask questions and clarify their understanding of each other's field of study and offered opportunities to gain insights through each other. The dialogue was then transcribed, emerging themes were identified, and the dialogue was jointly drafted to fit the flow and readability of an article.

Results of the Diffractive Encounters
In the following section, we share meaningful examples from the cogenerative dialogue organised by themes (see the whole dialogue in the appendix). The examples begin with a brief overview of the materials or topics that were discussed, followed by dialogue excerpts.

It is important, however, to keep the overall approach in mind, that we started individually by preparing written material that was joined as an annotated bibliography (Godoy et al., 2020) and that the dialogue represents a moment when each ESR re-encounters their selections, to reflect and explain oneself and the others why the selected material was of importance. This was followed by the others not only reflecting on what they had previously read in the bibliography but also to the reflections of the person explaining their choices. The dialogue excerpts are presented again from a third-person view, reflecting on our dialogue. However, we decided against de-personifying ourselves by calling ourselves ESR 1,2 or 3, since it felt like too much of a charade to pretend that we were not present.

The Material Forces of Text on Disciplinary Habitus
The dialogue started by each person reflecting on the reasons why they had chosen a particular text to share with the others. Each person presented selected theoretical ideas they felt were important in their field and to their work. Leire, for example, said:

> In my work, I am focusing on citizen ownership of energy. Therefore, the literature I selected highlights and explains the diversity of citizen ownership models, and introduces the benefits associated with citizen ownership, and the main barriers and drivers for its implementation. (Leire, appendix, para. 1, p. 20)

> I also included a paper I wrote together with my colleagues Gorroño-Albizu, Karl Sperling and Søren Djørup (2019) because it shows also my theoretical approach and explains that there are interrelations between the institutional incentives (the rules of the game), the transition of the energy system (technologies and actions implemented) and the ownership of the energy system. (Leire, appendix, para. 2, p. 22)

Leire emphasises where she places herself within her discipline. The materials she selected are part of her disciplinary journey that have become part of her self. She even chose one of her own publications to signify her feeling of identity within the community. A similar observation can be made about Jaqueline starting by positioning herself:

> The focus of my PhD research is on sociotechnical energy cultures and how they shape decision-making processes, including, e.g., disciplinary thinking. (Jaqueline, appendix, para. 3, p. 24)

And Jinxi says:

> In my selection, I was mainly focused on the literature I wanted to read for my study, and I put less focus on the perspectives of our joint work package. (Jinxi, appendix, para. 4, p. 29)

Jinxi is very clear that the material she (and the others) work with is powerful, since it describes also the norms and values of a community of practice that they want to become part of. It was important to her to express that it needed to be her priority to share what was relevant to her work.

Agential Cuts of Ideas

The text materials that were selected 'left a mark' on everyone. Furthermore, as everyone interfered in some way in the cogenerative dialogue event breaking down the barrier between text and humans, new understanding was formed in an in-between existence. Leire explains, for example, to the others, her choice of an article:

> The paper by Sherry Arnstein (1969) helps me to understand the difference between participation and ownership. (Leire, appendix, para. 1, p. 24)

She continues:

> In my PhD, I want to focus on the highest level of participation, 'citizen control,' which I understand as 'citizen ownership,' since it gives those actors control over the process and the outcome. The reason why I am looking into this is because it may offer different benefits or more benefits than other lower degrees of citizen participation in the energy transition. (Leire, appendix, para. 2, p. 24)

Likewise, Jaqueline notes that:

> Jessica Smith and Mette Smith (2017) focus on the anthropology of energy, highlighting the value of using ethnography to understand energy and its connection to ethics. The relevance of their work for my research is that an anthropological view allows examining people's experiences and micro-decisions about how they engage with energy as a daily

cultural practice. An anthropological approach focuses on cultural constructs around the world and highlights how culture has influenced the discourses and the ways energy is produced, distributed and consumed by societies. (Jaqueline, appendix, para. 6, p. 27)

They are, for us, examples of agential cuts and 'what the agential cut does provide is a contingent resolution of the ontological inseparability within the phenomenon hence the conditions for... description: that is, it enables an ... account of marks on bodies, but only within the particular phenomenon' (Barad, 2007, p. 348). The examples show these selected phenomena and the marks they had left. The examples also show the focus on the process of our interactions, and, by doing so, we can identify the boundaries in between. Jinxi's mark shows appreciation as well as how the ideas opened up new spaces to become a practitioner in her discipline:

> When comparing the agent-based model to the optimisation model, they found out that due to the limitation of information, companies will under/overinvest in different periods of the model run. [….] My current work will add more characteristics to the model. For example, we have added different lengths of foresight (e.g., companies have different expectations about how fast future carbon prices increase) for different companies. Also, we add new technology choices, such as biogas plants, into the model. (Jinxi, appendix, para. 2, p. 30)

It is important that the text and the ideas the individuals identified delineate roles that are and could be played in the disciplinary arrangement. This focus also emphasises what Barad describes as an ethics of knowledge, since it involves respecting and reflecting the complexity of different knowledge fields (Braidotti, 2013).

String Figures and Diffracting Stories

Donna Haraway (2016) uses the metaphor of playing a game of string figures and that, when string figures are passed from one player to another, they change into new figures. She refers to the passing and receiving of patterns. She also explains that this process requires that we hold still to pay attention. In the next example, Jinxi reflects on how her listening to Jaqueline's explanations had reshaped her own thinking:

> I think there are two main takeaways for me. Jaqueline is looking at how decisions are being made in reality, the actual, 'real' factors when people make decisions. Compared to my model, I focused on the company's economic performance, and the company only aims to maximise its profitability, which is an oversimplification of reality. Jaqueline's discussion helps me to see the limitations of my model. (Jinxi, appendix, para. 4, p. 28)

This example should not be interpreted as an example of mirroring where ideas are bounced off, untainted and undisturbed, but rather that ideas are diffracted and that, by paying attention to the process, we can identify differences and relationalities and trace entanglements of ontologies. This next example is where Jinxi's 'string figure' is passed on to Jaqueline and then further to Leire.

> What intrigues me is how my research could contribute to Jinxi's work, for example, the possibility of expanding the factors of decision making for the different agents? Together we could consider some values-based decision-making aspects. For example, even if nuclear power plants are the most profitable for some companies, some countries have decided to go against new nuclear investments due to the risk of environmental disasters and nuclear waste. Including factors that shape decision-making, for example, due to social or environmental values and not just economic aspects, could influence the way investments are perceived. (Jaqueline, appendix, para. 5, p. 30)

Leire continues; she receives the thinking from Jaqueline:

> I think that's a really good point, Jaqueline. When I listen to Jinxi explaining her model, I am also thinking: How could we analyse how different ownership models could result in different investment strategies? For example, a certain profitability rate might be good for a stakeholder or a type of owner, but it might not be enough for another, the risk levels might be perceived in a different way, and the type of portfolio that you have may lead you to make different types of investments. (Leire, appendix, para. 6, p. 30)

The diffractive engagement between the three ESRs feels like a string figure game where discoveries are made when ontological strings are pulled into new directions.

Discussion: Diffractive Reading and its Implications for Interdisciplinary Energy Research

Karen Barad (2007) reminds us that the process of analysis through diffractive reading is not a means to reduce data, much like coding would achieve. Rather, it is about the deliberate process of continuing with ideas and moving thinking into new and different directions. It is about allowing subjectivities to emerge and give them presence, since, for Barad, knowing describes the process of intra-acting with materials, because 'knowing is a matter of part of the world making itself intelligible to another part of the world' (p. 185). Diffractive reading results in rhizomatic analytical productions, not hierarchical or linear ones (Mazzei, 2014). Our joint discussion showed us that interdisciplinary thinking is not so much about the aim to arrive at a common denominator but to open up new points of departure. It would be counterproductive to try and summarise the key points made in order to

show a reduction of ideas, but it is necessary to show the details of how new pathways emerged.

This is an argument against binary thinking and the possibility of paying necessary attention to complexities. Multi-voicedness played an important role in the process of this activity, including the preparation of this article, since it pays tribute to processes and complexities; we will therefore identify our voices for the reader in the discussion part once more. It will start with a reflection on the process by **Kathrin**:

Karen Barad writes that when we engage with each other through diffraction, we are intra-acting with materials and human actors. There is the text you produced and the responses to the text but also to each other's responses. At each turn, something new and slightly different is being generated. Looking through the materials produced and our joint activity, I think that for Jaqueline, the production of the bibliography, reading the materials of the others, and the diffractive cogenerative dialogue resulted in a new understanding of the theories she is working with. For instance, I saw that when Jaqueline thought about what Bruno Latour's Actor Network Theory means in the light of Jinxi's research. She is trying to start from unconnected actor particularities in her explanation about companies and investments to draw connections between them and foreground investments as actants and argues for the use of a relational ontology. In her response to what she read and heard from the others, she is aiming to reduce proximities, which is what Latour describes as an important aim of this theory (Latour, 1996). Listening to Jinxi, my impression is that her engagement with the ideas the others are using resulted in thinking about further complexities of her own work, perhaps aspects that were not so prominent previously; aspects to do with ethics, for example, but also what it might mean to collaborate in a greater multidisciplinary team. To me, Jinxi took the activity and the different ideas that were presented to think about what she could learn from this for her own work. Not necessarily to make any sudden changes to her own work but rather to sensitise her own thinking about possible directions that one could take when you are researching companies as actors in a transitioning process. Leire's thoughts highlighted to me her realisation of what different 'languages' are used, and that collaboration of any kind would need to understand each other's vocabulary. I could see in the dialogue how all Jinxi, Jaqueline and Leire expressed different yet related aspects of the meaningfulness of their research and selected theories that were materialised through their joint bibliography. Their own work but also that of the others gained more meaning through the act of articulation that emerged, and this, to me, resonates strongly with Barad's descriptions of what intra-action means and that it makes the boundaries and components of a phenomena more meaningful (Barad, 2007, p. 333).

Leire: First of all, I feel this could expand my own understanding of the problem I am dealing with by getting familiar with new literature and different ways of

looking at the same issue. Second, the annotated bibliography and the cogenerative dialogue have enabled us to change the focus of our discussions from 'this is what I am doing and how much I have progressed since we met last' (which is the normal set-up in project meetings) to 'this is how I understand the problem and the reasons why I am doing the research the way I am doing it.' For me, the new focus has enabled a qualitative leap in understanding each other's projects and research fields, which will certainly enrich our future discussions and accelerate the process of finding relevant interdisciplinary research questions.

Jinxi: I thought that the annotated bibliography and the cogenerative dialogue were very helpful learning opportunities for me. My research has benefited from this process in various ways. First, I have learned how an actor can be studied from different angles and what theories are applied in other disciplines in the context of the energy transition. This has broadened my knowledge. Secondly, by explaining my research to researchers in different fields, I become more aware of the limitations of my research, since the methods and assumptions that I apply in my study might sound peculiar in a different discipline. Lastly, when I look back at the recorded dialogue (in the appendix), I also realise that the research itself is a learning process. Since the cogenerative dialogue took place, my research has been advanced. If I were asked the same question again (as in the dialogue in the appendix), my answers would not be completely the same.

Jaqueline: The cogenerative dialogue approach allowed me to unpack the underlying theories in the articles we chose, relating those to our fields of research and how they link to other fields. The process of working together showed me also the problem of energy transition as an integral part of society, and that the scientific limitations of each other's area require that interdisciplinary research overcomes disciplinary limitations.

The process we have shown here in the three phases was a necessary framework that structured the joint engagement. The bibliography tasked each person to focus only on a few select but key theories that were thought to be important and provided a necessary materialisation of ideas to share and think with. They were material 'things' that allowed us to coordinate individual collections of perspectives, fruitful, and necessary boundary objects (Leigh Star & R. Griesemer, 1989) with a specific purpose. The cogenerative dialogue approach was needed first to structure us coming together and thinking together; it also allowed us to show our individual voices in the materialised version of the dialogue to preserve the disciplinary fields and demarcations. The dialogue allowed us to expand our understanding of methods, concepts, and normative statements used in the energy sector, similarly to the experiences reported by Janet Stephenson (2017), who captured interdisciplinary meaning-making in energy research.

Conclusion

In this paper, we have shared a structured process of intra-action with text and our dialogue that allowed us to explore important ideas and what they may mean for the ambition toward interdisciplinary understandings. This engagement also allows that, through the process of diffraction, the habitus of each person encountered new fields (Costa & Murphy, 2015, p. 15). To us, those understandings do not imply that one has to give up disciplinary expertise quite the contrary; it strengthens disciplinary knowledge through the emphasis on being reflective since understandings are thought with by those unfamiliar with the methods and theories that are being utilised. For one's own research field, it means that, through this engagement, one 'make[s] the familiar strange' (see, for example, Fillery-Travis & Robinson [2018]) as a pedagogical intervention of thinking. The possibilities of taking a Baradian turn allowed us to emphasise our differences while decentering our interpretations to produce 'multiplicity, ambiguity, and incoherent subjectivity' (Mazzei, 2014, p. 743).

Why is this approach needed, for instance, in the field of energy research? Because interdisciplinarity is described as some form of ideal, but we felt that, when it comes to the implementation, there is much underexplored potential. Put into the context of the research project ENSYSTRA, transitions towards sustainable energy systems are no doubt key to curbing the worrying trend and trajectory of a future world exhausting its resources and impacting negatively on the world's climate. However, our awareness of the complexity that sustainable energy transitions require makes it imperative to challenge conventional ways of thinking since we have come to the realisation that old trajectories are insufficient or counterproductive to such ambitions. What we have shown here is a necessary step to learn how to think with complexity in mind in order to calibrate and adjust our perceptions about each other's and our own practices. Taking time to work with one's habitus is made easier if it is done in dialogue with others and allows to illuminate 'practices, beliefs, perceptions, and feelings' (Nowicka, 2015, p. 102). We also learnt that this process takes time and effort; however, we experienced these seeming deviations to a busy PhD schedule as necessary and rewarding since complex systems, such as energy systems, make predictions based on classical approaches only problematic and insufficient (Norberg & Cumming, 2008), and we believe that if we are working towards systematic changes through adaptations of systems, we need to start by familiarising ourselves more deeply with our own processes of thinking and taking time to be impressed by the ideas coming from others and taking note why this exposure left marks on our thinking.

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Appendix: The Material Forces of Texts: Sharing and Thinking with Different Ideas

Kathrin: The main aim of us talking now is to discuss the annotated bibliography you have put together. My role here is that of a moderator, driving reflections on the intertwining of the knowledge by asking you questions. Let us begin with the selected literature and start with Leire's research on ownership models.

Leire: In my work, I am focusing on citizen ownership of energy. Therefore, the literature I selected highlights and explains the diversity of citizen ownership models, and introduces the benefits associated with citizen ownership, and the main barriers and drivers for its implementation. The first paper, by Gordon Walker & Patrick Devine-Wright (2008), discerns two dimensions of ownership: of the 'process' (the decision-making power) and of the 'outcome' (how the benefits are shared). The paper highlights the heterogeneous understanding of 'community energy' between stakeholders in the UK — which reflects the still present confusion about this concept in Europe and abroad. The authors argue that an open understanding of the concept can be beneficial because it allows for several forms of citizen ownership to flourish. However, they also warn about the risk of losing some of the potential benefits commonly associated with community renewable energy, like enhancing local acceptance of energy projects, which may require open and participatory processes as well as local and inclusive distribution of project benefits.

The paper by Sherry Arnstein (1969) helps me to understand the difference between participation and ownership. There are different degrees of citizen participation which the author groups in three main categories: non-participation, tokenism, and citizen control (in ascendant order of citizen power). In *non-participation* approaches, citizens hold no decision-power and the aim of engaging them in the process is to 'cure' or 'educate' them. In tokenism, citizens may be 'informed' or even 'consulted' – however, their suggestions and opinions may not be considered for decision-making. The next step in the ladder is *placation*, which works as a kind of compensation. One example of this can be seen in Denmark in the context of people being economically compensated when wind turbines are built. Finally, we have the two degrees of *citizen control:* 'partnerships' (where citizens start having negotiation power), 'delegation' (from decision-making authorities into citizens) and 'citizen control' (the highest level, where citizens hold the majority of the power in the decision-making process).

In my PhD, I want to focus on the highest level of participation, 'citizen control,' which I understand as 'citizen ownership,' since it gives those actors control over the process and the outcome. The reason why I am looking into this is because it may offer different benefits or more benefits than other lower degrees of citizen participation in the energy transition.

I also chose to include Vasco Brummer's (2018) structured literature review on 'community energy' to elaborate on the understanding of the concept as well as on the identified benefits and barriers. I am drawn to it because the author claims that some of the confusion surrounding the concept 'community energy' comes from the multiple understandings of 'community' and concludes that 'community energy' (generally) implies some sustainable energy technology solution, participatory, and democratic processes where centralistic structures and participation without power are excluded. Furthermore, he points out that the barriers for citizen energy project implementation may be related to formal institutions, informal institutions, or organisations' characteristics. According to the author, the former is the most hampering.

The paper by Jarra Hicks and Nicola Ison (2018) is presenting a theoretical framework based on the analysis of 25 projects in Australia, the US, and Europe, where they argue that contextual factors and motivations create the basis for many of the decisions that are made in citizen energy projects (in terms of community engagement, governance, technology, scale, and finance), and therefore they lead to different types of projects and project benefits. I think the framework helps explain why there is so much diversity in citizen ownership and, most importantly, it clarifies that the benefits of citizen energy projects are dependent on contextual factors, motivations, and project characteristics.

I also included a paper I wrote together with my colleagues Gorroño-Albizu, Karl Sperling and Søren Djørup (2019) because it shows also my theoretical approach and explains that there are interrelations between the institutional incentives (the rules of the game), the transition of the energy system (technologies and actions implemented) and the ownership of the energy system. Looking into the literature, the links between the institutional incentives and the energy system transition have been analysed. Likewise, the link between the institutional incentives and the ownership of energy systems has also been analysed. However, what has not been analysed that much is how the technical energy system and ownership can shape each other or change each other.

I think the paper is also important because it shows the development of categories that describe the main distinct characteristics of different citizen ownership models regarding the project benefits. The categories include the geographical scope (local or distant), the type of profits (unlimited private profit, limited private profit or for common good) and the distribution of benefits (inclusive or exclusive). The categories can be very useful to advance the understanding of the 'right' ownership models to promote certain policy goals, e.g., local acceptance, capital contribution, etc.

And here is an example of the positive impacts that you can expect from local ownership. Anna Berka and Emily Creamer (2018) present a structured literature review and conclude that impacts may be 'longer-term indirect impacts' or 'direct impacts' from the projects. Like Jarra Hicks and Nicola Ison (2018), Anna Berka and Emily Creamer (2018) point out, achieving the identified positive impacts will depend on some preconditions and on the type of project. Furthermore, they tried to link the impacts that you can have to the type of projects that you are developing and to some preconditions.

To sum up, the main points of the literature I selected are that: (a) there is no common understanding of the concept of 'community energy' and citizen energy projects are very diverse; (b) the development of citizen energy projects is dependent on multiple factors, importantly (formal) institutional incentives; (c) many positive benefits have been associated to citizen energy projects, but the benefits are determined by contextual factors, motivations, and project characteristics; and (d) there is an important research gap regarding which types of citizen ownership projects (and ownership models) may (or may not) deliver certain benefits under different sociotechnical contexts.

Kathrin: Jinxi and Jaqueline, Leire's selected literature has a very specific meaning for her work, but what does it mean to you and your thinking? After listening to her now and having read about those ideas before our meeting, what is your response to those ideas? Will they shape your understanding, and, if so, in what way?

Jaqueline: I have learned that conceptualising ownership models focuses the need on the study of contextual factors and motivations underlying decision-making and that this can help understand the link between ownership and the technological choices people make and

how it influences participation of the society on the energy transition. While this is not something that Leire is studying, it is the focus of my PhD. When you are studying energy cultures (for example, Stephenson et al. [2010]), you need to take into account what motivation and values underpin the technology development of different actors. I can see here a shared focus with direct collaboration opportunities.

Jinxi: Leire's bibliography helped me, first of all, to understand her research better and why she wanted to research this. It also helps me to realise that there are different types of companies. When I do my research, there is an oversimplification of what entails a company, with a lot of assumptions taking place. But Leire's research considers different types of companies that are characterised by different types of ownerships. The result of considering different types of ownerships is that it will lead to different investment strategies by companies that may result in different outcomes of technologies. By combining Leire's understanding with mine, I think I will be able to diversify an investment study for other company types.

Kathrin: I think that's very interesting. Let us move to the literature Jaqueline highlighted in her bibliography.

Jaqueline: The focus of my PhD research is on sociotechnical energy cultures and how they shape decision-making processes, including, e.g., disciplinary thinking.
   The first reference I selected is a book called 'Down to Earth: Politics in the New Climatic Regime' where the author, Bruno Latour (2018), reflects on the geopolitical challenges of the climate crisis, the need to rediscover what it means to be human beyond the dichotomies of local and global meanwhile acknowledging the nature-as-an actor (Godoy, 2020). The reflection of Latour on the Anthropocene era we live in had a deep impact on my thinking, and I think it can elude the experts who lead strategies for the energy transition to understand why there are climate deniers. By acknowledging this behaviour, it is possible to find common grounds and look for solutions.
   The second paper I choose is by Elizabeth Shove and Gordon Walker (2014), where the sociologists propose to understand energy as a set of practices that are part of the 'ongoing reproduction of complexes of social practices' (p. 41). It is an alternative view of energy as a 'resource base' (linked to the systems needed for the management of energy in society) (p. 41) because it gives agency to individuals to transform their daily practices when using energy. The authors focus on energy demand as a social practice to reflect on energy use in connection with the practices taking place in society. In the light of those practices, strategies for reducing energy demand are drawn.
   The next paper that I chose reflects on energy decisions considering principles of justice and ethics by Benjamin Sovacool et al. (2016). The authors provide a framework for energy projects to guide decision-making processes based on principles of, e.g., affordability, transparency, equity and responsibility (just to mention a few). The framework can guide the decisions of policymakers, investors, and/or consumers, for example, to consider the displacement of citizens when power plants are built, or dealing with questions of fuel pollution, and more.
   Jessica Smith and Mette Smith (2017) focus on the anthropology of energy, highlighting the value of using ethnography to understand energy and its connection to ethics. The relevance of their work for my research is that an anthropological view allows examining people´s experiences and micro-decisions about how they engage with energy as

a daily cultural practice. An anthropological approach focuses on cultural constructs around the world and highlights how culture has influenced the discourses and the ways energy is produced, distributed and consumed by societies.

Catherine Wong (2016) uses an Actor Network Theory (ANT) approach, and this means she considers humans and non-human actors alike to be in a connected network and that they can and will influence each other. For interdisciplinary energy research, this means that researchers should be more reflexive about the assumptions that underpin their research and the influences that shape their disciplinary knowledge. Reflexivity in energy research can support the inclusion of social aspects (justice, ethical practices) and their connection to technical assemblages.

Kathrin: Leire and Jinxi, what do you take away from this? Do these ideas take you into new or different directions of thinking?

Jinxi: I think there are two main takeaways for me. Jaqueline is looking at how decisions are being made in reality, the actual, 'real' factors when people make decisions. Compared to my model, I focused on the company's economic performance, and the company only aims to maximise its profitability, which is an oversimplification of reality. Jaqueline's discussion helps me to see the limitations in my model. Another takeaway is the reflection of what is 'energy.' When I think about energy, I consider energy to be power and electricity. Jaqueline looks at energy at a broader level. For me, it means that there are different definitions of energy. It makes me aware that I am only looking at a narrow theme.

Kathrin: And what about you, Leire?

Leire: For me, there were many interesting points here. One is that it helps me reflect on how I look at the issues that we have in front of us for the energy transition and better understand some of my theoretical approaches and give some structure to some ideas shaping my research. It was interesting to read, for example, about Elizabeth Shove and Gordon Walker's (2014) paper and that there are these two different understandings of energy. Since reading about this, I have adopted the second one. I argue that actors' participation and interactions influence energy systems, including what we consume, how we consume it, the type of implemented technologies, and so on. Even if I do not apply this idea in my research so clearly, I can see this can lead to very different research questions if we question our understanding of energy. I am also intrigued to look into the energy justice framework, and maybe I can include some of these in the assessments to analyse the different ownership models and business models in my research.

Kathrin: Let us now move to Jinxi's bibliography and her thoughts.

Jinxi: In my selection, I was mainly focused on the literature I wanted to read for my study, and I put less focus on the perspectives of our joint work package. The literature that I selected fits into three categories. The first category is the investment cost (for investment in new power plants). I chose it because, for companies, the cost is a very important factor. There is a lot of literature that analysed how costs impact companies' decision-making processes. And also, there is literature discussing how the carbon tax can influence investment decisions. The second category is the investment strategy. The literature discusses investment decision criteria, for example, companies' risk perception of

investments. The third category of my literature is about the impact on electricity systems from the intermittency of renewable energy, especially wind and solar, when, for example, backup energy sources are required.

From my bibliography, I would like to talk primarily about the work by Emma Jonson, Christian Azar, Kristian Lindgren and Liv Lundberg (2020). My current work is based on and expands on this study. The article, using an agent-based model, investigated how companies make investments in new power plants in the electricity system. They compare their results with an optimisation model to look at the differences between these two types of models. The methodology used in this paper is as follows: the company evaluates different types of technologies, including coal, gas, wind, solar, and nuclear power plants. After the evaluation, the companies decide to invest in a plant that they think would bring the most profit. The companies know the current (electricity and carbon) price, but they don't know how the price will develop in the future. The price forecast is therefore limited (the same for every company), this may imply decisions upon not optimised information, and this can lead to investments that would run at losses. In the article, each company makes investment decisions once a year, and the model runs for 70 years. In this study, they used German electricity demand data, and start the model with only coal and gas. The model also includes a carbon tax. After running the model for 70 years, the electricity system is transferred from a fossil fuel-based to a carbon-neutral system, which consists of solar, wind, nuclear, and gas-fired power plants. When comparing the agent-based model to the optimisation model, they found out that due to the limitation of information, companies will under/overinvest in different periods of the model run. My current work will add more characteristics to the model. For example, we have added different lengths of foresight (e.g., companies have different expectations about how fast future carbon prices increase) for different companies. Also, we add new technology choices, such as biogas plants, into the model.

Kathrin: Do these ideas trigger new questions or ideas for you, Jaqueline and Leire?

Jaqueline: What intrigues me is how my research could contribute to Jinxi's work, for example, the possibility of expanding the factors of decision making for the different agents? Together we could consider some values-based decision-making aspects. For example, even if nuclear power plants are the most profitable for some companies, some countries have decided to go against new nuclear investments due to the risk of environmental disasters and nuclear waste. Including factors that shape decision making, for example, due to social or environmental values, and not just economic aspects, could influence the way investments are perceived.

Leire: I think that's a really good point, Jaqueline. When I listen to Jinxi explaining her model, I am also thinking: How could we analyse how different ownership models could result in different investment strategies? For example, a certain profitability rate might be good for a stakeholder or a type of owner, but it might not be enough for another, the risk levels might be perceived in a different way, and the type of portfolio that you have may lead you to make different types of investments.

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Kathrin: Us coming together here today is about talking about the text material you put together for each other and perhaps the wider group. In many ways, it is about the generation of questions that comes from talking to each other. So, maybe it will be useful if

you start by explaining to each other the role of the bibliography for your thinking, why you selected these texts and what you hoped to achieve through this interaction so new questions can arise.

Jaqueline: For me, the energy transition is an interdisciplinary matter. I realised very quickly that it is very complex to understand if and how disciplinary research projects overlap. Actually, Berth Danermark (2019) calls this cross-disciplinary understanding, and it means that there needs to be room or space for cooperation to develop new knowledge or solutions. In my perspective, having a common/shared understanding of each other's topic is the first stage of starting a collaboration process. In many of the discussions that we had before, I was unsure what the others meant when they used specific concepts or terminology that I was unfamiliar with. Working on the annotated bibliography and discussing ideas opened up my perceptions of the energy area. It also made it possible to develop my own and then a common vocabulary so we could be on the same page when we talk with each other. The collection of papers in the bibliography allowed me to reflect on my primary research field (sociotechnical energy systems) and on how I can contribute to the overall ENSYSTRA project aims (e.g., what research questions I can help to answer). Besides, it contributed to not only thinking about my specific area but discovering broader approaches that I now believe to be essential for researching energy transitions. I had to stay open to new and old methodologies and challenges that may come from other fields. I also learned that there is an ontological determination of methods, which are complimentary at many levels, e.g., one to disclose structures and another to investigate intentions.

Jinxi: I would like to use this opportunity to reflect on this activity on three levels which I think are important. First, on a personal level, I found that the preparation of this annotated bibliography is a little bit similar to the literature review and helped me to find out what other people have done in my field, so I could identify where I can contribute to my research area (Kamler & Thomson, 2006). The second perspective is on our work package level and the things we do together. Engaging in this process helps me to find out what other ESRs are doing, and I can learn something extra for my research. Since the three of us are in one work package, this can also help us to improve our collaboration because if we understand each other's work, we can discuss things with each other more in-depth. The third perspective is on the ENSYSTRA project level. Bridle, Vrieling, Cardillo, Araya and Hinojosa (2013) note, 'A major advantage of interdisciplinary encounters is the opportunity they provide for open communication' (p. 22). I think by making this annotated bibliography, we can show the other work packages what we (WP3) are doing and how are we working together as a work package.

Leire: We are part of a complex project. However, being an early career researcher makes it even more complicated because we need to familiarise ourselves with our research field as well as with the research fields of the others to be able to understand all the issues that are discussed in this project. However, only through this process can we find out how we can maximise our joint contribution through interdisciplinary approaches. One part of the problem is that we are not familiar with all the vocabulary that others use, and it is, therefore, necessary to follow the discussions when we meet. That is why I saw the annotated bibliography and the possibility of using tools like visual representations or relevant diagrams as a first step to build some shared basic knowledge, which would make

it possible to understand each other better. As a result, I expect that it will be easier to work together and learn from each other.

Kathrin: This is also echoed again in Bridle, Vrieling, Cardillo, Araya and Hinojosa's (2013) work when they write that success in interdisciplinary projects is dependent on people's willingness to listen to each other and be curious about each other's field of study. If you wanted to write a paper together, what would you still need to find out or understand?

Leire: We have tried to discuss that in various meetings over several months. It was not easy for us to see the links between the individual PhD projects. Even in our work package, where we are all studying actor behaviour and interactions, we are focusing on different stakeholders, and are using different methods, etc. All the collaboration proposals we came up with would have required that somebody has to deviate from their individual research project. At some point, we realised that to formulate a common problem and research questions, we needed to understand each other's project better so that we identify meaningful links and connections and work on something that would be useful for the three of us and still be able to complete our PhD projects.

Kathrin: In a way, you represent different stakeholders who want to find ways to participate and collaborate with each other. O'Brien, Marzano, and White (2013) describe quite nicely that stakeholders vary in their levels of interest, their use of different modes of knowledge products, and that this empowers some and disempowers others. Participation, on the other hand, is about empowerment, and this opening up of different views is key in interdisciplinary research. In your case, and, since you pointed this out earlier, it may be that the key differences are the different levels of focus on understanding how sustainable energy transitions are depending on actor behaviour. Let us explore who is an actor in this constellation. Depending on the theoretical framework you utilise, each of you will have different answers to this question.

Jaqueline: In my case, I am not making a distinction between human actors and non-human actors because I am adopting the approach of Actor-Network Theory from Bruno Latour.

Kathrin: So, who is an actor for you, Jinxi?

Jinxi: The actors in my research are quite specific; they are the energy companies that invest in new power plants. So, compared to (the actor in) Jaqueline´s (research), they are very specific.

Kathrin: Jaqueline, you talk about non-human actors. Could you give an example?

Jaqueline: I will try and explain it by looking at Jinxi's research focus. Investments are non-human actors. They operate as actants in a network and are connected to other actors, including to the person from within the company or the institution who decides which technology to invest in, which then influences how investments are made.

Kathrin: This is quite an interesting point. So Jinxi, how do you feel about this take on actors and actor behaviour?

Jinxi: Actually, even though I say it's an energy company when a company invests, it is still the people who work in and manage a company that make the investment decision. I think, still, it is the humans' decision, but at a company level.

Kathrin: But how do you work with this notion of a company being an actor? How do you describe a company?

Jinxi: I do this by applying a computational model called the Agent-Based Modelling for sociotechnical systems (see, for example, Van Dam et al. [2012]). In the model, we determine the goal of a company, e.g., to make a (maximum) profit. We identify this as a decision-making criterion that is simply based on which technology will generate the most profit (e.g., similar approach is used by Kraan et al. [2018]). If investing in solar plants will bring (the company) the most profits, then the company will decide to invest in solar power plants. So, it is a calculation or prediction of the profitability of different types of power plants.

Kathrin: So, the decisions are based on actors' investment behaviour?

Jinxi: What I just explained is about how companies use different criteria to make an investment, but all the criteria are still focused on profits only. However, I think that other variables (like ethics when mitigating climate change) are important elements to verify the influence of investments in future studies. To ensure a sustainable transition of the energy system, we should also consider not only the economic aspect but also the societal and ecological aspects of the transition.

Kathrin: Leire, who are the actors in your project?

Leire: I focus on energy companies and ownership. I am particularly interested in energy companies with local consumers and the resulting ownership models (Gorroño-Albizu et al., 2019). These companies may provide different energy services, and belong to different energy sectors, etc. I also investigate the context they are embedded in, including the institutional incentive system, the available material resources and their interactions with other stakeholders (e.g., local authorities, electricity transmission system operators, end consumers, etc.). In my theoretical approach, the institutional incentive system, the energy system transition and the actors' participation and interactions are interrelated and influence each other.

Kathrin: Can you give us a bit more detail about the actors and what defines them?

Leire: I compare different ownership and business models of energy companies in relation to their ability to address the main organisational challenges of implementing and operating (local) renewable energy systems with integrated sectors, i.e., smart energy systems (see also Gorroño-Albizu (2020).

Kathrin: Jaqueline, who are the actors that you are examining?

Jaqueline: Being more specific, I am interested in the actors that are producing knowledge, and those in charge of implementing solutions for sustainable energy transitions in the North Sea region. I am looking at actors at a micro level, individuals who identify themselves as being part of organisations or institutions, but not the individuals at the household level.