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RECONCILING THE COMPETING PROCESSES IN A DIGITAL TRANSFORMATION TOWARDS SUSTAINABILITY

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RECONCILING THE COMPETING PROCESSES IN A DIGITAL TRANSFORMATION TOWARDS SUSTAINABILITY

BY
ALISA ANANJEVA

DISSERTATION SUBMITTED 2023

AALBORG UNIVERSITY
DENMARK

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by Alisa Ananjeva

AALBORG UNIVERSITY
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THE AUTHOR

Alisa Ananjeva began her academic carrier in 2020 as a Ph.D. fellow at the Department of Computer Science at Aalborg University and part of the HCC group. Alisa's research interest lies in the interface between information systems and human-computer interaction. She is interested in problem-based research and research methodologies such as action research, action case studies, and longitudinal case studies. In addition, Alisa is interested in understanding change. She is driven by uncovering and understanding the complexities of seemingly simple actions that constitute the software development processes. This interest originates from her belief that in order to achieve change on a larger scale, we ought to first focus on the small transformative actions that constitute large-scale change. Thus, as a researcher, she strives to understand how and why small changes occur in situated practice.

ABSTRACT

In this dissertation, I investegate how system development organizations navigate competing processes in a digital transformation towards sustainability. Climate change is one of greatest challenges of our time. Digital transformation can help mitigate climate change by showing how digital technologies can (re)define our sustainability practices. However, the literature on digital transformation towards sustainability is dispersed and characterized by multiple competing processes. These competing processes are tensions that arise from different theoretical viewpoints. I do not argue whether some of the competing processes in the digital transformation towards sustainability are preferable to others – they are all valid from their points of view. These different points of view offer alternative explanations for the role of digital technology in solving the wicked problem of climate change. The contradictions and competition are inevitable in this process because there are no right or wrong answers - only answers that are better or worse from different points of view. Thus, there is no clear path to guide the practitioners and researchers in developing sustainable digital solutions. Against this background, I present the research question of this dissertation:

How do system development organizations navigate competing concerns in a digital transformation towards sustainability?

In answering this research question, I have identified four different process views on digital transformation that compete with one another: Optimization, Eco-feedback, Reflection, and Participation. These views are based on different assumptions regarding environmental sustainability, the problem at hand, and the solution. Based on this understanding, I propose a framework for recognizing and understanding these competing views. Furthermore, through a longitudinal case study, I found that navigating competing concerns in a digital transformation towards sustainability involves a process of reconciliation. This process involves legitimizing and addressing the competing concerns and is crucial for a successful digital transformation towards sustainability. I found that practitioners engaged in this transformation do not follow a single predominant process view but instead collaborate and reciprocate to navigate their journey towards sustainability. I propose that the reconciliation process is ongoing, and practitioners continuously review and adapt their past actions to fit current problems and future plans. The notion of reconciliation emphasizes that solving the problem of climate change through digital transformation is a complex and ongoing process that does not always result in a clear resolution.

DANSK RESUMÉ

I denne afhandling undersøger jeg, hvordan systemudviklingsorganisationer navigerer i konkurrerende processer i en digital transformation mod bæredygtighed. Klimaforandringerne er en af vor tids største udfordringer. Digital transformation kan hjælpe med at afbøde klimaændringer ved at vise, hvordan digitale teknologier kan (om)definere vores bæredygtighedspraksiser. Litteraturen om digital transformation mod bæredygtighed er dog delt - præget af flere konkurrerende processer. Disse konkurrerende processer er spændinger, der opstår fra forskellige synspunkter. Jeg argumenterer ikke for, om nogle af de konkurrerende processer i den digitale transformation mod bæredygtighed er at foretrække frem for andre – de er alle gyldige fra hver deres synspunkt. Disse forskellige synspunkter tilbyder alternative forklaringer på den rolle, som digital teknologi spiller i løsningen af det *wicked problem* med klimaændringer. Modsætningerne og konkurrencen er uundgåelige i denne proces, fordi der ikke er nogen rigtige eller forkerte svar - kun svar, der er bedre eller dårligere fra forskellige synspunkter. Der er således ingen klar vej til at vejlede praktikere og forskere i at udvikle bæredygtige digitale løsninger. Der er således ingen klar vej til at vejlede praktikere og forskere i at udvikle bæredygtige digitale løsninger. På den baggrund er dette, præsenterer jeg afhandlings forskningsspørgsmål:

Hvordan navigerer systemudviklingsorganisationer konkurrerende bekymringer i en digital transformation mod bæredygtighed?

I besvarelsen af dette forskningsspørgsmål har jeg identificeret fire forskellige processyn på digital transformation, der konkurrerer med hinanden: Optimering, Eco-feedback, Reflektion og Deltagelse. Disse synspunkter er baseret på forskellige antagelser om hvad bæredygtighed indebærer, det aktuelle problem og løsningen. På baggrund af denne forståelse foreslår jeg en rammeværk for at anerkende og forstå disse konkurrerende synspunkter. Desuden fandt jeg gennem et longitudinelt casestudie, at det at navigere i konkurrerende bekymringer i en digital transformation mod bæredygtighed involverer en forsoningsproces. Denne proces involverer legitimering og adressering af de konkurrerende bekymringer og er afgørende for en vellykket digital transformation mod bæredygtighed. Jeg fandt ud af, at praktikere, der er engageret i denne transformation, ikke følger et enkelt fremherskende processyn, men i stedet samarbejder og gengælder for at navigere deres rejse mod bæredygtighed. Jeg foreslår, at forsoningsprocessen er i gang, og at praktikere løbende gennemgår og tilpasser deres tidligere handlinger, så de passer til nuværende problemer og fremtidige planer. Begrebet forsoning understreger, at løsning af problemet med klimaændringer gennem digital transformation er en kompleks og vedvarende proces, som ikke altid resulterer i en klar løsning.

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In writing my thesis, I had to reflect. Firstly, I looked back at my academic work over the last three years, which was humbling, painful, fun – literally every emotion on my emotional spectrum. Secondly, this reflection reminded me that a Ph.D. is a journey – something I sometimes forget while striving towards the end goal (the title). Finally, looking back, I remember people who made this journey meaningful, survivable, and enjoyable. Some people were there every step of the way, and others joined later, but I am grateful to you all.

Firstly, I would like to thank people from Aalborg Forsyning and Watts A/S for providing their time and knowledge and always being willing to tell me their stories that made this thesis possible. Furthermore, thank you to all my co-authors for the collaboration, insights, and expertise.

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Without all of you, I would not be writing these words.

Alisa

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Research Design chapter delves into the research approach, activities, and methods. The research approach in this thesis is a longitudinal case study.

Paper Contributions chapter reports on how each of the five papers featured in this thesis advances our understanding of how system development organizations navigate competing concerns in the digital transformation of district heating in Denmark. The papers are:

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- **[P2]** Infrastructuring in Digital Transformation: An Action Case Study of District Heating, *ECIS'21*
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Discussion chapter contains theoretical insights on how system development organizations navigate competing concerns in a digital transformation. The foundation for the theorizing is empirical data and relevant literature on digital transformation. Furthermore, this chapter argues how the key insights of this thesis support and advance current knowledge on digital transformation.

Conclusion chapter summarizes the thesis, presents the limitations of my longitudinal case study, and proposes future work.

1. INTRODUCTION

The transformative power of digital technology is evident in every aspect of our society. Our connectedness to the digital world has never been more ubiquitous, instant, and anticipated. We, the consumers, are adopting new technologies and technology-related practices. Anytime and anywhere, consumers of the digital can watch a movie, listen to a song, or order food – as stated by Ross, Beath, and Mocker (2019), 'We don't wonder why these things are possible; we simply expect them' (p. ix). Organizations are also changing due to "rapid changes in customer needs, emerging technologies, and competitive actions" (Pavlou and El Sawy, 2010, p. 444). As a response, the organizations are creating new business models (Berman, 2012), value propositions (Sebastian *et al.*, 2020), digital business ecosystems (El Sawy and Pereira, 2013), and new organizational identities (Wessel *et al.*, 2020). However, achieving the coveted change is not banal. Even though change is often described as good and necessary (Alvesson and Sveningsson, 2016), change can lead to entropy.

Fighting the tide of entropy is difficult; thus, organizations often struggle to navigate the digital landscape (Ross, Beath, Mocker, 2019). The struggle is described as the "knowing-doing gap," where the organizations are aware of the incoming change but are not doing enough to prepare for it (Kane, 2019). Often organizations are not agile or innovative enough to navigate the digital landscape (Kane, 2019). This landscape is characterized by turbulence and disruption, resulting in unpredictability, with many 'unknown unknowns' (El Sawy and Pereira, 2013), making it difficult for organizations to predict and control the outcomes of their efforts toward success (Hanelt *et al.*, 2021). Therefore, achieving digital success remains a challenge despite the imminent nature of change.

Digitalization is a force to be reckoned with, perceived by some as something beyond organizational control. However, digital technology is not solely a source of disruption; it can also act in a supportive capacity, enabling organizations to improve their business outcomes (Piccini, Gregory, Kolbe, 2015). Information Systems (IS) research discipline has been concerned with information technology (IT)-enabled organizational transformation for decades, seeking to understand "how interactions between organizational contexts and IT systems impact transformation" (Wessel *et al.*, 2020, p. 104). The IT-enabled organizational transformation process seeks to reinforce organizational identity by supporting the core value propositions through digital technology (Wessel *et al.*, 2020). In recent years a new form of digitally enabled organizational change has occupied academics and practitioners, namely, digital transformation.

1.1 DIGITAL TRANSFORMATION TOWARDS SUSTAINABILITY

The digital transformation process is often described in the literature as organizational concerns (Vial, 2019). However, the digital transformation process can go beyond an organization or even an inter-organizational setting – digital transformation has the potential to address the grand challenges of our society.

One of the most significant challenges of our time is climate change. Digital transformation can positively mitigate climate change through digital services that can (re)define our sustainability practices (Ågerfalk, Axelsson, Bergquist, 2022) on organizational and societal levels. In this process, the organizations need knowledge of environmental, economic, and social sustainability as well as the development of innovative technology, rapidly changing markets, multiple implementation domains, and customers [P3]. Sustainability is the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland and Khalid, 1987). This definition of sustainability provides a vision for sustainable development. However, it does not explain the present and future needs clearly, emphasizing the wicked nature of the sustainable development problem. This lack of clarity is also evident in the literature on digital transformation towards sustainability, characterized by multiple competing concerns. Competing concerns are inevitable in this process because "there are no right or wrong answers, only answers that are better or worse from different points of view" (Introne *et al.*, 2013, p. 45).

One stream of the literature suggests that people will act per the information available to them and consume in a manner that "provides them with the most personal gain at the least personal cost" (Strengers, 2011, p. 2136). From this point of view, digital transformation becomes a process of identifying how digital technology can provide information and awareness about the consumption (Froehlich, Findlater, Landay, 2010) to promote pro-environmental behavior in an individual or a group (Froehlich *et al.*, 2012).

Another literature stream advocates that our actions are anchored in the physical and digital artifacts and vice versa (Nicolini, 2012). This stream of literature critiques the process of informing and persuading through digital technology based on the rational-choice theory. Thus, this stream of literature focuses on the process of transforming everyday practices. In this digital transformation process, the researchers and designers focus on (re)defining what constitutes 'normal' behavior, e.g., *scripting* the digital technology, thus changing the social norm embedded in digital technology (Pierce, Schiano, Paulos, 2010).

Others view technology as the principal agent of social change (Wyatt, 2008). From this point of view, digital transformation can be a process of achieving full automatization - reducing human intervention to the minimum to achieve eco-

efficiency (Chen, Boudreau, Watson, 2008, p. 190). Less drastically, the process of digitalizing can also support and reinforce organizations in realizing their sustainability initiatives (Zeiss *et al.*, 2021).

There is also a process that favors the collaborative human agency of social change (Biørn-Hansen and Håkansson, 2018). This process challenges the notion of technological determinism and believes that people are the engines behind the change (Biørn-Hansen and Håkansson, 2018) and not simply a contributor to an unsustainable way of life or an entity that needs to be persuaded or reduced. Instead, the citizens should be involved in designing sustainable digital solutions, e.g., co-design smart cities to democratize the city's shared spaces (Heitlinger, Bryan-Kinns, Comber, 2019).

These competing concerns are alternative explanations for the role of digital technology and people in solving the wicked problem of climate change. These alternatives emphasize the lack of a clear path to help organizations navigate the digital transformation towards sustainability. In this process, the organizational capability to manage the contradictions they face is essential (Raisch and Birkinshaw, 2008). This capability is enhanced in inter-organizational settings (O'Reilly III and Tushman, 2013). Thus, to navigate competing concerns, the organizations become increasingly more interconnected (El Sawy and Pereira, 2013) - collaborating to minimize the risk of failure (Berman, Saul and Marshall, 2014). However, we lack an understanding of *how* organizations in inter-organizational settings navigate competing concerns in a digital transformation towards sustainability while co-evolving within the increasingly interconnected digital landscape (Hanelt *et al.*, 2021).

1.2 RESEARCH QUESTION

Climate change is one of the most wicked problems of our lifetime - it is widespread and intensifying, which is why we desperately need to solve this problem. Digital transformation has the potential to help mitigate this wicked problem (Watson, Boudreau, Chen, 2010; Bengtsson and Ågerfalk, 2011; Seidel, Recker, vom Brocke, 2013). Digital transformation is a process of (re)defining the core value propositions of an organization (Wessel *et al.*, 2020). In this process, an organization needs to face the contradictions inescapable in the digital landscape (Raisch and Birkinshaw, 2008). In a digital transformation towards sustainability, these contradictions - or competing concerns - are evident in the alternative explanations for the role of digital technology in solving the wicked problem of climate change.

For example, digital transformation towards sustainability can be viewed as a process of achieving full automatization (Chen, Boudreau, Watson, 2008, p. 190). On the other hand, others might emphasize people as the engines behind the change (Biørn-Hansen and Håkansson, 2018). From this point of view, digital technology's role is to

increase people's engagement in sustainable development (Seidel *et al.*, 2018). These competing concerns indicate that there is no one path to guide researchers and practitioners in sustainable development - "there are no right or wrong answers, only answers that are better or worse from different points of view" (Introne *et al*., 2013, p. 45). Thus, in a digital transformation towards sustainability, the organizational ability to manage the contradictions becomes essential (Raisch and Birkinshaw, 2008). Moreover, this ability is enhanced in inter-organizational settings (O'Reilly III and Tushman, 2013), which is why organizations become increasingly more interconnected (El Sawy and Pereira, 2013). That being said, we lack an understanding of *how* system development organizations collaboratively navigate competing concerns in a digital transformation towards sustainability. Against this backdrop, I present my research question:

How do system development organizations navigate competing concerns in a digital transformation towards sustainability?

To answer my research question, I conducted a longitudinal case study of a digital transformation of district heating in Aalborg, Denmark. This case study is a story of how two system development organizations navigate the complexities of (re)defining what is an energy provider, an energy consumer, and energy consumption in an increasingly digital world.

Over the two years, I have followed Watts A/S (a software development organization) and Aalborg Forsyning (an energy system development organization). I found their partnering fascinating because, despite their apparent differences, they successfully navigated the digitalization of district heating in Aalborg, Denmark. Watts A/S is a born-digital organization with a flat hierarchy and an agile mindset. Aalborg Forsyning, on the other hand, is a large public organization with clear hierarchical structures and a planning mindset. These two system development organizations did not buy or sell services from each other. Instead, they shared expertise and ressources to develop a mobile application that provides hourly energy consumption to the consumers – the Watts. Watts A/S benefited from this collaboration by gaining access to consumption data, a more extensive user base, and expertise in the district heating domain. Aalborg Forsyning benefited from access to software developers and a digital solution already used by electricity consumers.

Despite their differences in size, culture, and structure, Watts A/S and Aalborg Forsyning successfully navigated the competing concerns they faced in their digital transformation journey toward sustainability. Additionally, I studied district heating consumers in Aalborg municipality to understand how they view the solutions developed in this partnership and identify consumers' concerns regarding the digitalization of district heating.

Lastly, to answer the research question, I have conducted a developmental literature review to nuance my understanding of the competing concerns in the process of digital transformation towards sustainability. This literature review aims to disentangle the competing concerns to uncover some underlying assumptions on a digital transformation towards sustainability.

In the following chapters, I will delve into related research (Chapter 2), a theoretical framework that supports my research study (Chapter 3), research design (Chapter 4), and paper contributions (Chapter 5). In Chapter 6, I present my theorizing and express how it contributed to the extant research. Next, I suggest an explanation theory (Gregor, 2006) that seeks to explain *how* system development organizations navigate competing concerns in a digital transformation towards sustainability. This explanation theory is built on the insights presented in five full papers summarizing my research. Finally, in Chapter 7, I conclude this thesis and present the limitations of my study that motivate future research.

2. BACKGROUND

"Change is the only constant "– this quote by an ancient Greek philosopher, Heraclitus, has never been more relevant than it is today. The emergence and diffusion of new technologies such as artificial intelligence, blockchain, and virtual reality are ongoingly changing our society (Kane, 2019). As a response, the organizations are creating new identities by (re)defining their core values (Wessel *et al.*, 2020) and becoming more malleable to survive in the turbulent digital landscape (El Sawy and Pereira, 2013). As a result, organizations are digitally transforming themselves. The digital transformation process also has the potential to help achieve sustainable development (Seidel, Recker, vom Brocke, 2013). Thus, the potential benefits of digital transformation can go beyond the organizational settings. In the following sections, I unfold the digital transformation phenomenon and present related research on how digital technology can help mitigate climate change.

2.1 DIGITAL TRANSFORMATION

Digital transformation has become an established theme in academia and practice (Hanelt *et al.*, 2021). Literature on digital transformation explores how companies transform themselves to succeed in an increasingly digital world (Nambisan, Wright, Feldman, 2019). However, there is no common understanding of digital transformation (Warner and Wäger, 2019). This process has been defined as *changes that digital technology causes or influences in all aspects of human life* (Stolterman and Fors, 2004). This definition expands the scope and scale of digital transformation by going beyond the organizational context. However, this definition is too abstract, deluding this process into everything (and consequently, nothing). Digital transformation can also be viewed *as organizational change that is triggered and shaped by a widespread diffusion of digital technologies* (Hanelt *et al.*, 2021). This definition, however, invites the question of whether the notion of a digital transformation is "an old wine in a new bottle" – a new label put on the well-established IT-enabled organizational transformation process. In answering this question, Wessel *et al.* (2020) have disentangled the two processes – IT-enabled organizational transformation and digital transformation. They found that digital transformation does not support the existent organizational identity and culture - as the IT-enabled organizational transformation process does – the outcome of digital transformation is a new organizational identity. The new organizational identity emerges from the (re)definition of the core value propositions of an organization (Wessel *et al.*, 2020). In this process, the organizations are also changing how they collaborate with other organizations - thus, creating new opportunities for value creation (Kopalle, Kumar, Subramaniam, 2020). For example, organizations establish cross-functional teams (Ross, Beath, Mocker, 2019), inter-organizational partnerships

(Bitran, Gurumurthi, Sam, 2007), or become part of digital business ecosystems (El Sawy and Pereira, 2013). The potential benefits of these changes are increased customer involvement and satisfaction (Piccini, Gregory, Kolbe, 2015) and a higher level of innovation (Nambisan, Wright, Feldman, 2019). That being said, achieving these potential benefits of digital transformation is "challenging managers across industries and contexts" (Hanelt *et al.*, 2021, p. 1160). Digital transformation is not trivial - it is an outcome of unforeseen processes and collaborative practices (Ulfsnes *et al.*, 2022; Stockhinger and Werner, 2022). The managerial action (e.g., changes in processes) creates a new organizational reality (Lindgren, Mathiassen, Schultze, 2021) – making the digital transformation process challenging to plan and execute (Ulfsnes *et al.*, 2022). As technology evolves rapidly, organizations must adapt and improvise their strategies to stay ahead of the competition and meet changing customer demands. Improvisation has become a critical aspect of IS strategy for organizations. Thus, in a digital transformation, the management can go beyond planning and embrace improvisation - balancing the freedom and constraints while aligning with the strategic intent (Stockhinger and Werner, 2022).

Based on these insights, in this thesis, I view digital transformation as i) a process of (re)defining the core value propositions of an organization and ii) a complex and ongoing process that is difficult to plan and execute due to its unpredictable nature.

2.2 GREEN INFORMATION SYSTEMS

Sustainability is a term that has been widely used and discussed in the last few decades, particularly in environmental protection. It refers to a development approach that prioritizes meeting society's current needs without compromising future generations' ability to meet their own needs. This definition was first introduced by (Brundtland and Khalid, 1987) and has since become a widely accepted framework for sustainable development.

Information systems (IS) research has been actively exploring sustainable solutions for over a decade. IS researchers aim to conceptualize, analyze, and design innovative solutions to help organizations become more environmentally sustainable (Gholami *et al.*, 2016). In particular, Green IS research focuses on using digital technology to mitigate the effects of climate change and make it possible to anticipate the needs of tomorrow (Watson *et al.*, 2011). This research takes an applied and design-oriented approach and seeks to gain an in-depth understanding of stakeholders, routines, and digital capabilities to identify opportunities for using technology to support environmental sustainability (Recker, 2016; Hedman and Henningsson, 2016; Seidel *et al.*, 2018; Ågerfalk, Axelsson, Bergquist, 2022).

For example, Seidel *et al.* (2018) examine how IS can support sensemaking practices in environmental sustainability transformations. In this study, Seidel *et al*. (2018)

described what material properties of digital technology can afford sensemaking in an organization. They identified that sustainable digital technology should promote the interpretation of the information and give a space to challenge and share experiences and assumptions (Seidel *et al.*, 2018). In creating and disseminating information on environmental sustainability through digital technology, it is possible to introduce mutually pro-environmental beliefs, attitudes, and behavior in an organization (Molla, Abareshi, Cooper, 2014).

Furthermore, utilizing organizational IT resources can play a vital role in enabling organizations to communicate sustainability values to relevant stakeholders (Dao, Langella, Carbo, 2011). For example, IT resources can increase the success of a sustainability champion - an individual who advocates for sustainable values and works towards their promotion within the organization (Hedman and Henningsson, 2016). This champion can act as a catalyst for disseminating sustainable values among the employees. Another Green IS concern is *how* to develop sustainable digital technology. For example, Zeiss *et al.* (2021) propose minimizing the input of technology and closing material loops towards a circular economic model in IS research.

Furthermore, it is essential to note that while the previously mentioned Green IS research has provided valuable insights, researchers still need to shift their focus from design orientation to one that prioritizes impact (Gholami *et al.*, 2016). This can be achieved by actively collaborating with practitioners and working to solve practical problems related to sustainability (Malhotra, Melville, Watson, 2013). By going beyond descriptions and predictions toward an active engagement with multiple stakeholders in the design and development of Green IS, the researchers gain a unique opportunity to contribute to the discourse surrounding climate change and understand the role that technology can play in addressing this complex issue (Ågerfalk, Axelsson, Bergquist, 2022). However, while engaging with multiple stakeholders, IS researchers must monitor the differing incentives and potential competing concerns that can arise in a digital transformation towards sustainability (Ågerfalk, Axelsson, Bergquist, 2022).

Against this background, when concerned with the digital transformation towards sustainability, in this thesis, I focus on i) collaborative actions addressing practical sustainability problems and ii) unfolding the different roles that technology and humans can play in addressing this complex issue. However, there are limited studies on *how* the process of a digital transformation towards sustainability unfolds in practice. Therefore, in the following chapter, I present a process theory as a theoretical framework for my thesis.

3. THEORETICAL FRAMEWORK

The digital transformation process towards sustainable development is full of many unknown unknowns, making it hard for practitioners and researchers to predict the outcomes of our actions. Thus, we are required to think in terms of the possible rather than probable (Feldman and Sengupta, 2020), to study emergence rather than dissect accomplished change (Tsoukas and Chia, 2002), and to turn away from what *is* (being) towards what we *do* (becoming) (Pentland *et al.*, 2022).

3.1 PROCESS THEORY

There are two perspectives on what a process is. The first perspective views a process as a *category of concepts* of individual and organizational actions – dealing with identifying antecedents or consequences of change (Van De Ven, 2007, p. 196). Viewing a process from this perspective enables the researchers to answer *if* a change occurred (Van De Ven, 2007). The second understanding of a process views a process as a sequence of events that describe *how* a process unfolds over time – focusing on identifying incidents and activities through a narrative (Van De Ven, 2007, p. 197). In this thesis, I aim to explain *how* system development organizations navigate competing concerns in a digital transformation towards sustainability, which is why I pertain to the second view on a process. From this perspective, a process theory explains *how* and *why* a process unfolds over time (Van De Ven, 2007). There are four ideal types of process theories in the context of organizational development and change (Van de Ven and Poole, 1995, p. 520) (see Figure 1):

1. The first ideal type is a *life cycle* model, which explains the change as a progression of necessary sequences. Progress is prescribed in a sequence of actions and regulated by a logical program defined before the cycle begins.
2. The second ideal type is a *teleological* model; it views change as a cycle of "goal formulation, implementation, evaluation, and modification." This model incorporates the notion of equifinality – there are multiple ways of achieving a single goal.
3. The third ideal type is a *dialectical* model, which states that development occurs when the status quo is disrupted, and opposing forces (thesis and antithesis) are made salient. Then, the change manifests in a synthesis. Synthesis becomes a thesis, and the cycle repeats.
4. The fourth ideal type is an *evolutionary* model, which describes the change as a progression of variation (emergence of new forms), selection (selection of more suited forms), and retention (maintenance of organizational forms). This ideal type can be described as development through natural selection.

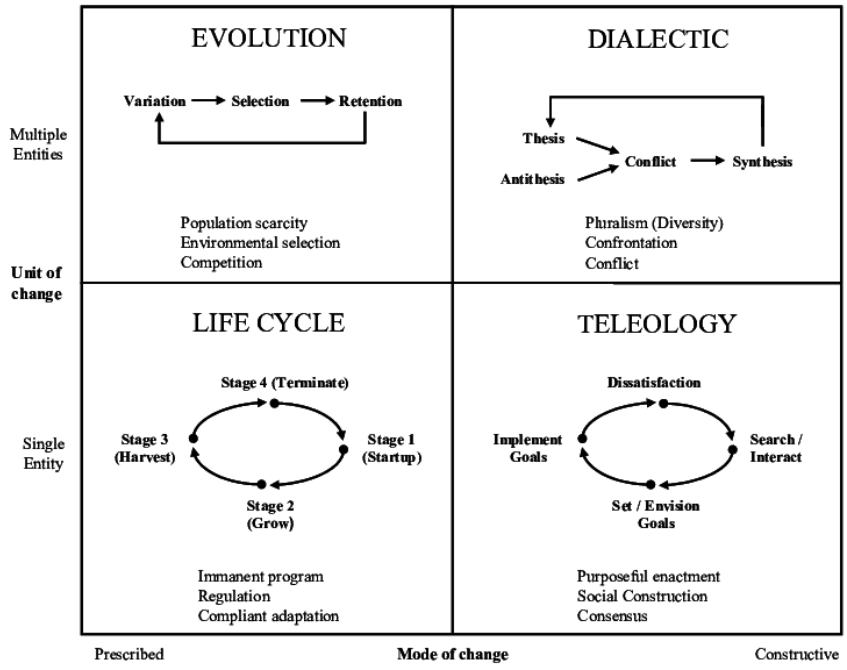

Figure 1 Process theories of organizational development and change (Van de Ven and Poole, 1995)

The theoretical framework of my thesis is the process multiplicity theory (Pentland *et al.*, 2020), which is closest to a 'theological' process theory. In a theological model, development implies action toward the goal without specifying a specific trajectory (Van de Ven and Poole, 1995, p. 516). I find this theory applicable to my thesis because I try to understand *how*, in a digital transformation towards sustainable development (the goal), the system development organizations navigate competing concerns (the multiple ways a goal can be achieved).

Process multiplicity is the duality of 'one' and 'many' (Pentland *et al.*, 2020), implying that a single process can unfold in a multiplicity of ways. Furthermore, it highlights the idea that a process is not just a series of self-contained actions but rather a set of interrelated actions constantly changing and evolving over time – they are becoming in relation to other actions (Feldman, 2016).

To better understand the concept of process multiplicity, Pentland *et al.* (2020) employ the metaphor of crossing a meadow. Crossing the meadow is considered the

'one,' while the multiple ways this process can be carried out are considered the 'many.' A new path may be created each time the process is performed, but people are often prone to following established paths, making these paths a dynamic product of past performances. The complete set of possible ways to cross the meadow is defined as a 'space of possible paths.'

Process multiplicity theory challenges the notion of predefined relationships and actions and invites us to consider the process as a whole rather than just individual performances (Scott and Orlikowski, 2014, p. 873). To truly grasp the idea of a process as a relational and performative entity, it is necessary to capture multiple performances and identify the actions taken for granted within the process (such as workarounds and improvisation) (Pentland *et al.*, 2020). Problematizing these taken-for-granted actions makes it possible to challenge assumptions and reveal tensions that cannot be identified through a single perspective (Pentland *et al.*, 2020). Therefore, process studies, as Van De Ven (2007) proposed, are useful when exploring complex phenomena involving multiple elements and capturing how change unfolds over time. By studying processes as a whole, it becomes possible to understand the interrelationships between actions and identify the dynamic nature of change.

The theoretical framing of this thesis consists of the following realizations: i) a process is a sequence of events that describe *how* a process unfolds over time, ii) a single process can unfold in a multiplicity of ways, and iii) it is necessary to capture multiple performances and identify the actions that are taken for granted within the process.

How researchers understand a process influences research design – the methods used, the analysis of the empirical data, and how we frame the contributions. Change can be captured through "longitudinal observations of an entity over two or more points in time […] and then noticing difference over time" (Van De Ven, 2007, p. 196). Through longitudinal studies, the researchers allow the change to reveal itself (Pettigrew, 1990) – presenting the nuances in situated and complex problematic situations. Thus, in the following chapter, I present my research design to explain how I studied the process of digital transformation towards sustainability.

4. RESEARCH DESIGN

In this chapter, I present the methodology applied to answer the research question of this thesis. As I have described in the previous chapter, it is difficult to capture the ongoing change (Van De Ven, 2007). The change, in my case, is the ongoing process of digitally transforming district heating in Aalborg, Denmark. Change (or a process) can best be captured by longitudinal observations of two or more points in time (Van De Ven, 2007, p. 196). Thus, I conducted a *longitudinal case study* (Pettigrew, 1990) to explore *how* organizations navigate competing concerns from various stakeholders.

4.1 LONGITUDINAL CASE STUDY

The research question of this thesis asks the question: *how* do organizations *navigate* competing concerns in a *digital transformation* towards sustainability*?* The emphasized words (how, navigate, and digital transformation) imply a study of a processual phenomenon. "How" implies a *theory for understanding* how - or why - things are (Gregor, 2006). "Navigate" refers to the process of finding directions during a journey. "Digital transformation" is a process of (re)defining the core value propositions (Wessel *et al.*, 2020). One way of studying change (or a process) is through a *longitudinal case study* (Pettigrew, 1990). Longitudinal case studies require a significant investment of time, resources, and effort, and they can be affected by issues such as participant attrition, measurement error, and the difficulty of interpreting the multifaceted data (Pettigrew, 1990). By following an organization's change over time, researchers can gain insight into the challenges and the strategies and tactics used to overcome them (Pettigrew, 1990). Moreover, through longitudinal case studies, researchers capture the various contextual factors that influence organizational change. This is necessary because organizational change is a complex and dynamic process that is shaped by multiple factors, requiring an in-depth and comprehensive analysis (Pettigrew, 1990). Thus, longitudinal case studies are valuable for understanding complex and dynamic organizational change (e.g., a digital transformation towards sustainability). However, longitudinal case studies can be challenging to conduct. One of the main challenges is to maintain scientific rigor. Longitudinal studies involve collecting data at multiple points in time, and it can be difficult to ensure that data collection methods are consistent across all time points (Pettigrew, 1990). Any changes in data collection methods or instruments can introduce potential bias and threaten the validity of the study's findings.

Another challenge is maintaining the *quality* of data over time. As the study progresses, changes in the research environment can make it difficult to maintain the quality and accuracy of the data collected (Pettigrew, 1990). Finally, longitudinal studies may also face challenges in terms of generalizability (Pettigrew, 1990). Due

to the complex and context-specific nature of the change being studied, it can be difficult to generalize the study's findings beyond the specific context in which it was conducted. In addition, it is essential to consider the transferability of the study's findings to other settings (Gregor, 2006). Addressing these challenges requires careful planning and execution of the study, including attention to data collection and management and quality control (Pettigrew, 1990). Ultimately, a rigorous and well-designed longitudinal case study can provide valuable insights into the dynamics of complex phenomena over time (Van De Ven, 2007).

4.2 THE CASE OF AALBORG FORSYNING AND WATTS A/S

This thesis delves into the partnership between Aalborg Forsyning and Watts A/S, two system development organizations that have come together to transform Denmark's energy sector digitally. I found their partnering suitable for understanding how organizations navigate competing concerns in a digital transformation journey because the two companies successfully collaborated on digitalizing district heating in Aalborg - despite their apparent differences.

Aalborg Forsyning is a utility company – an energy system development organization. Aalborg Forsyning is a larger company with around 350 employees and a clear hierarchical structure. As a utility company, Aalborg Forsyning is developing and maintaining the physical and digital infrastructure of energy systems in Aalborg Municipality in Denmark (e.g., district heating, water, and waste management). Thus, Aalborg Forsyning is part of the critical infrastructure in Denmark. Being part of the critical infrastructure (digital and physical) obliges them to have a planning mindset; their systems must be robust, secure, and reliable.

In this longitudinal case study, I studied the digitalization of the district heating system. District heating is a system for providing heat energy to buildings from a central source, usually through a network of insulated pipes (Lund, 2014). The central source can be a power plant or a waste-to-energy facility. The heat is usually generated by burning fossil fuels, biomass, or solar energy. The heated water is then distributed through the network of pipes to buildings in the surrounding area. District heating can also be more environmentally friendly because it can use renewable energy sources and generate less pollution than individual heating systems (Lund, 2014).

For over a decade, sustainable heating consumption has been a focus for Aalborg Forsyning. They made this decision because the local coal-fired power plant, which currently provides heat to Aalborg municipality, is scheduled to shut down in 2028. With these upcoming changes in mind, Aalborg Forsyning aims to digitally transform district heating through information technology to engage consumers and promote more efficient and effective heat consumption. To accomplish this objective, Aalborg

Forsyning partnered with Watts A/S, a software development company, and electricity provider that specializes in creating an energy assistant application.

Watts A/S, on the other hand, was founded in 2016 as an independent company in Andel – the largest energy concern in Denmark. Watts A/S is a born-digital, small company with 32 employees. They strive towards having a flat hierarchy and describe their organizational structure as a modular, reverse pyramid. Thus, Watts A/S is a flexible and dynamic organization with an agile mindset.

Watts A/S aims to mitigate climate change by creating technological solutions that reduce people's energy consumption and change habits towards a more sustainable future. Throughout the years, Watts A/S has developed a portfolio of technology products that help consumers to become more environmentally sustainable. However, the Watts – a free energy assistant application – is their primary product. In developing this application, Watts A/S found that they could not fight climate change alone, so they sought collaborations and partnerships with other organizations to join the efforts in this journey – such as Aalborg Forsyning.

Together the two organizations aim to promote sustainable development in the energy sector in Denmark. While other utility companies are involved in this effort, their physical and digital infrastructures did not support the Watts application fully. Nonetheless, Aalborg Forsyning and Watts A/S collaborated to develop the Watts application for tracking and predicting heat consumption. During my two-year study of the collaboration between the two organizations (2019-2021), I observed that they did not engage in buying or selling services or products from each other. Rather, they combined their resources and capabilities to develop a working solution for heat consumption tracking and prediction. The collaboration was beneficial for Watts A/S in terms of accessing the data, an expanded user base, and access to domain experts in district heating. Meanwhile, Aalborg Forsyning benefited from access to software developers and an already working digital solution that had proven useful in tracking and predicting electricity consumption.

Both organizations shared an overall concern for sustainable energy consumption in their digitalization efforts. The collaboration has been observed to have developed and evolved, only strengthening over the years. Due to this persistence, I consider this collaboration an interesting case study of how two system organizations navigate competing concerns in their digital transformation towards sustainability.

Furthermore, as researchers, we were also engaged with the two organizations. We helped them with our expertise in digitalization and how this process can further sustainable consumer consumption. For example, we conducted a questionnaire sent out to district heating consumers in Aalborg Municipality. We interpreted and communicated insights from this questionnaire to both organizations, thus, increasing their understanding of consumers' heat consumption.

4.3 DATA COLLECTION

A longitudinal case study requires careful planning and execution of the study. Consistency in data collection, analysis, and synthesis is essential to maintaining scientific rigor (Pettigrew, 1990). A longitudinal case study requires the use of multiple sources of data. In my case study, I conducted participant observations, observations, focus groups, semi-structured interviews, and narrative interviews. The research methodology employed in this study entailed collecting data from various central stakeholders (partnering organizations and consumers). My Ph.D. scholarship is part of an "Energisynk" project - many observations and interviews were conducted in collaboration with fellow researchers from this project. Thus, I sometimes use "we" in this section to emphasize the collaborative effort of acquiring the data. To gain a complete overview of the data-collecting activities, see Table 1.

Initially, we participated in a meetings spanning two years, from fall 2018 to fall 2020, with Aalborg Forsyning. In these meetings, we were participant observers and engaged in informal discussions centered around plans for the digital transformation of district heating. The primary objectives of these meetings were i) to gain a better appreciation of the district heating domain and ii) to explore the challenges and potential solutions that Aalborg Forsyning faces in transforming district heating. The meeting participants included employees from Aalborg Forsyning responsible for digitalization and researchers from energy planning, sustainable building design, and digitalization. Furthermore, I have participated as an observer in pod council meetings with Watts A/S. The objective of these observations was i) to better understand their organizational structure, ii) system development practices, and iii) decision-making processes.

To gain insight into the perspective of consumers regarding the digital transformation, a series of interviews were conducted. In the fall of 2019, focus group interviews were held with seven participants who did not yet have access to their heat data in the Watts application. The focus group interviews aimed to gain insight into participants' expectations, level of interest in the Watts, and prior experiences with reducing heating consumption. Additionally, in the spring and fall of 2020, semi-structured interviews were conducted with six participants before and after they gained access to their heating data in the Watts application. The interviews were centered on participants' experiences with heating before and after using the Watts application. Of particular interest was how the Watts application impacted their thinking regarding heating practices and investment in energy renovation.

To better understand the situation from an organizational perspective, we conducted semi-structured interviews with representatives of Aalborg Forsyning and Watts A/S responsible for leading the digital transformation. The primary objective of these interviews was to gain insight into the decision-making process and rationale behind key decisions.

Data collecting activities	
Observations/Informal meetings	• 4 x Aalborg Forsyning • 2 x Watts
Focus group interview	• 7 consumers of district heating in Aalborg Municipality
Watts A/S **12 Semi-structured interviews** **(February 2020 – August 2022)**	• 5 x Section Manager responsible for R&D • 3 x Section Manager responsible for partnering with Utility companies • 2 x CEO responsible for the vision and mission of Watts A/S • 2 x Data engineer
Aalborg Forsyning **8 Semi-structured interviews** **(September 2020 – February 2022)**	• 5 x Project Manager responsible for Watts application roll-out • 2 x IT-Project Manager responsible for digital infrastructure • 1 x Head of Energy Supply er responsible for providing vision and mission for the DT of district heating.
Watts application users **14 Semi-structured interviews** **(April 2020 – November 2020)**	• 2 x Finn, a Construction Engineer – uses the app monthly • 2 x Svend, a Municipal Worker – uses the app weekly • 2 x Anne, a Municipal Worker – uses the app daily • 2 x Erik, a Taxi Driver – uses the app monthly • 2 x Karen, a retired Secretary – uses the app monthly • 2 x Steve, researcher – uses the app bi-annually • 2 x John, a utility worker – uses the app monthly

Table 1 Data collecting activities

In addition, I was keen to document the various performances of collaborative partnering that occurred between the two organizations. A useful method for capturing such performances is through narrative (Pentland, 1999). As a result, I carried out narrative interviewing (Jovchelovitch and Bauer, 2000) with decision-makers from both organizations over the course of two years (2019-2021) to record actions that facilitated collaboration between the two organizations, such as problem-solving. Throughout the interviews, I used interview guides and recorded the conversations for further analysis.

4.4 DATA ANALYSIS

After collecting the data, I applied the abductive way of reasoning to analyze the data. Abductive reasoning differs from the traditional inductive and deductive methods of data analysis. Induction is a data-driven analysis, which states that data can lead to theory (Brinkmann, 2014). A deduction is a theory-driven form of analyzing data. In the deductive way of thinking, we collect and analyze the data through a theoretical framework (Brinkmann, 2014).

The abductive approach to analysis, on the other hand, is a form of reasoning that focuses on understanding a specific situation through sensemaking – dynamically shifting between being data- and theory-driven (Brinkmann, 2014). Abduction is a process of navigating the uncertainty a researcher can experience during data analysis (breakdown-driven analysis). Thus, abduction is useful when trying to understand and act in uncertain situations (Brinkmann, 2014), e.g., a situation with many unknown unknowns, such as an ongoing digital transformation of the energy sector in Denmark. Furthermore, abductive thinking complements a longitudinal case study. The purpose of a longitudinal case study is to capture a complex reality. This process involves cycles of expanding complexity and simplification – which is enabled by abductive thinking.

Furthermore, I used thematic analysis (Braun and Clarke, 2006) to identify patterns and themes in the collected data. Thematic analysis and adductive thinking are complementary methods. Thematic analysis was used to identify and analyze the main themes that emerged from the data, such as *competing concerns* and *collaborative problem-solving* [P1, P2, P3, P5]. Adductive thinking was used to generate and test theories based on the data, such as navigating the four competing process views on digital transformation towards sustainability [P4, P5]. The thematic analysis provided a structured approach to organizing and categorizing the data, while adductive thinking allowed for exploring new insights and connections between the themes [P4, P5]. By using both methods, I could provide a comprehensive understanding of the complex and dynamic nature of navigating digital transformation in the energy sector in Aalborg, Denmark [P1, P2, P3, P5]. Overall, combining thematic analysis and adductive thinking proved to be a powerful approach for analyzing and interpreting qualitative data.

In [P1], I focused on understanding the situation prior to digitalization to uncover potential competing concerns and why this transformation is necessary.

In [P2], we collaborated with Aalborg Forsyning and Watts A/S to understand what structural changes are required and what type of work is required to achieve these changes (e.g., inter-organizational partnering). In [P2], I analyzed the empirical data in the following steps:

1. Listen to all recordings, transcribe, then read all transcriptions and other texts to familiarize us with the empirical data.

2. Based on the framework of infrastructure, infrastructuring, and breakdowns, critically identify quotes in the data and code these appropriately.
   a) The quotes are selected and coded if they shed light on 'what' or 'why.'
   b) What infrastructuring work are stakeholders doing?
   c) Why are they doing this, and what is the breakdown?

3. Link the quotes and codes to the infrastructure to identify how infrastructuring and breakdowns relate to infrastructure features.

4. Elicit the defining infrastructuring types from this and structure the network of quotes and codes accordingly.

In [P3], I went into more detail, focusing on collaborative problem-solving between Aalborg Forsyning and Watts A/S to understand how they partner toward the shared goal of sustainable heating consumption. In [P3], I went through the same steps as [P2] but with a focus on problem-solving and utilizing process multiplicity theory (Pentland *et al.*, 2020).

Concurrently with the previous three studies [P1-3], I conducted a literature review [P4] to understand the current research on digital transformation toward sustainability. In the 32 articles selected, I have identified the problem, the solution, and the transformation. Across these three aspects, I found four different process views on digital transformation toward sustainability. Thus, I conducted a *developmental literature review* (Templier and Pare, 2015) and developed a framework that captures and conceptualizes what characterizes the competing concerns.

In [P5], I empirically elaborated this theory of competing process views. The four views were operationalized by codifying their distinct criteria for developing digital solutions that enable environmental sustainable. For instance, the optimization process view was characterized by codes such as *service*, *infrastructure*, *process*, *efficiency*, and *effectiveness*. I then examined if the problems, solutions, and different views on sustainability identified in the research were evident in the collaborative problem-solving between Aalborg Forsyning and Watts A/S. For example, if a chosen quote suggested efficiency and effectiveness, I related it to the optimization view. The quotes were analyzed to elucidate how organizations navigated this digital transformation journey. In the selected quotes, I searched for key actions in the digital transformation that ensured the continuation of their collaborative journey (e.g., the two organizations reciprocated each other's process views). Through this process, I have made three propositions on what *navigating* digital transformation towards sustainability means. Thus, I finished my abductive data analysis process.

5. PAPER CONTRIBUTIONS

In this thesis, I explore how system development companies navigate competing concerns in a digital transformation toward sustainability. I conducted a longitudinal case study and a developmental literature review to explore this phenomenon. Insights from these research activities are summarized in five research papers (see Figure 2).

Each paper investigates different aspects of navigating competing concerns in a digital transformation journey. [P1] investigates the case of district heating from an energy consumers' perspective. This paper revealed competing concerns between energy consumers and energy providers. The identified competing concerns regarded energy literacy, motivation for heat reduction, and the role of technology in supporting heat reduction. These concerns emphasize the need for behavioral and structural changes to facilitate the energy sector's digital transformation. The identified demand for structural changes motivated [P2], which explores how these structural changes can be achieved. [P2] emphasizes the inevitability of the competing concerns in a digital transformation process and highlights that system development organizations navigate these concerns by responding to breakdowns experienced by many stakeholders (e.g., consumers and partnering organizations). This paper revealed *what* type of work is required in navigating competing concerns in a digital transformation. This insight raised the question of *how* this collaborative process unfolds on an inter-organizational level. I answered this question in [P3], which explores how system development organizations collaborate in the digital transformation of district heating in Denmark. In [P3], this inter-organizational collaboration is viewed as a problem-solving process. This problem-solving between system development organizations is adapting to the problematic situations they encounter in their digital transformation journey. Thus, [P3] provides an empirical understanding of how organizations are dynamically navigating the energy sector's digital transformation in Denmark. Together, the insights from [P1], [P2], and [P3] have motivated [P4], which presents theoretical insights into competing concerns in the related literature. The purpose of [P4] is to uncover the competing views on the digital transformation process towards sustainability. These competing views are evident in the alternative explanations of the role of the digital in solving the problem of climate change. In [P4], I have identified four process views on the problems, solutions, and underlying assumptions on sustainability: Optimization, Eco-feedback, Reflection, and Participation. The insight from [P3] - problem-solving is an essential process in a digital transformation journey - and the four competing views on a digital transformation towards sustainability, uncovered in [P4], has motivated [P5]. In this paper, I explore how system development organizations navigate the four competing process views. I found that system development organizations navigate the competing views on digital transformation by i) reciprocating each other process views, ii) responding to the turbulence with a multiplicity of process views, and iii) reflectively reassessing the past to improve and plan for the future.

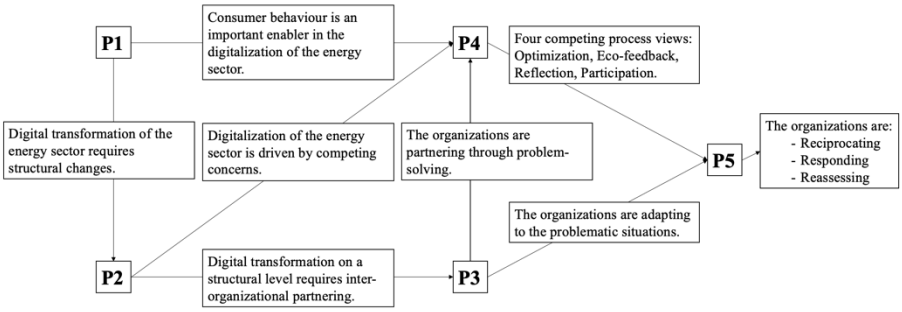

Figure 2 Learning journey over time summarized in five papers.

My learning journey has led me to explain how system development organizations navigate competing concerns in a digital transformation journey towards sustainability. The explanation is illustrated through my theory of reconciling the competing process views in a digital transformation towards sustainability (presented in Chapter 6).

[P#]	PUBLICATION INFROMATION
[P1]	Svangren, M. K., Jensen, L. K., **Ananjeva, A.**, Persson, J. S., Nielsen, P. A., Brunsgaard, C., & Sperling, K. (2020). Investigating One-Time Actions for Domestic Energy Reduction: The Case of District Heating. *In Proceedings of the 11th Nordic Conference on Human-Computer Interaction (NordiCHI'20)*
[P2]	Svangren, M. K., **Ananjeva, A.**, Persson, J. S., Mouritsen, L. K. E., Nielsen, P. A., & Sperling, K. (2021) Infrastructuring in Digital Transformation: An Action Case Study of District Heating. *Twenty-ninth European Conference of Information Systems (ECIS'21)*
[P3]	**Ananjeva, A.**, Persson, J. S. & Nielsen, P. A., (2022) How organizations collaborate in the Digital Transformation towards Sustainability. *Thirtieth European Conference on Information Systems (ECIS'22)*
[P4]	**Ananjeva, A.**, Persson, J. S. & Nielsen, P. A., (2023) Digital Transformation towards Sustainability: Four views on problem-solving in the literature. Submitted to: *Fourteenth Scandinavian Conference on Information Systems (SCIS2023)*
[P5]	**Ananjeva, A**., Persson, J. S. & Nielsen, P. A., (2022) Digital Transformation towards Sustainability: A Case Study of Process Views in District Heating, *The 13th International Conference on Software Business (ICSOB'22)*

Table 2 Paper publication information

5.1 [P1] ONE-TIME ACTIONS FOR ENERGY REDUCTION

Research question: How and why do people take one-time actions that lead to long-term energy reductions in people's homes, and how can digital technology facilitate it?

The motivation for this paper was to gain the heat consumers' and the system development organizations' views on the potential competing concerns in a digital transformation of district heating in Denmark. Information technology is often designed with the purpose of persuading people to change their behaviors to reduce energy consumption through eco-feedback (Kjeldskov *et al.*, 2015; Jensen, Kjeldskov, Skov, 2016). However, the long-term effectiveness of this approach has been questioned (Strengers, 2011; Hasselqvist, Bogdan, Kis, 2016). Therefore, this paper suggests that *one-time actions* (e.g., investing in energy-efficient technology or building renovations) could be more effective in achieving long-term energy reductions. That being said, there is a lack of research on how digital technology can facilitate one-time actions. To better understand the role of the digital in enabling one-time action, we conducted informal interviews with energy suppliers and focus-group interviews with representatives from seven households. The findings suggest that *energy literacy* (van den Broek, 2019), or knowledge about energy use and consequences, is essential for taking one-time actions. The system development organization stated that the consumers' ability to reduce their heat consumption depends on access to actionable consumption data. During the focus-group interview, the consumers discussed that the lack of access to consumption data, lack of knowledge about heat consumption, and the potential benefits of the one-time heat reduction actions hinders actionability.

Furthermore, the system development organization anticipated that energy consumption was not interesting for the consumers. However, the focus-group interview showed that consumers were motivated, usually by economic gains and concern for the environment. Lastly, the system development organization assumed that automatization should provide a long-lasting effect on a household's consumption. However, some consumers did not want to install more information technology in their households due to an overwhelming number of digital devices surrounding people. The interview participants also pointed out that more detailed data and personalized advice on the outcomes of one-time actions would be helpful. The identified competing concerns regard lack of energy literacy, varying motivation for heat reductions, and different views on the role of technology. These concerns emphasize the need for behavioral and structural changes to facilitate the digital transformation of the energy sector. Based on these findings, we suggest that digital solutions for energy reduction should facilitate one-time actions and behavior change.

5.2 [P2] INFRASTRUCTURING IN DIGITAL TRANSFORMATION

Research questions: What types of infrastructuring do stakeholders conduct as part of a digital transformation of district heating? What kinds of breakdowns trigger these stakeholders' infrastructuring?

This paper was motivated by the identified demand for structural changes [P1]. Therefore, in [P2], we aimed to explore how digital transformation can be viewed as infrastructuring work. We sought to identify breakdowns (Star and Ruhleder, 1994) that trigger infrastructuring (Pipek and Wulf, 2009) in a digital transformation of district heating. In this action case study [P2], we found three types of infrastructuring that resolve breakdowns. The first type of infrastructuring we identified was *digitalizing heat supply metering*, triggered by a breakdown of limited access and use of consumers' metering data. The second type was *digitalizing consumers' heating practices*, triggered by breakdowns in the ability to engage consumers in their heating practices. The third type was *digitalizing through partnering*, which was triggered by breakdowns in the system development organizations' access to knowledge on developing effective *digital* solutions for disseminating energy consumption.

We proposed a process theory to explain infrastructuring in a digital transformation of the energy sector in Denmark. According to our theory, digital transformation can be viewed as a two-way process that aims to improve the infrastructure by triggering significant change to its properties through infrastructuring work [P2]. This process consists of dynamic activities that individuals or organizations perform. Our research has shown that in a digital transformation within the public sector, partnerships and collaboration play a vital role. Thus, it is important to recognize that successful infrastructuring requires the involvement of multiple stakeholders, adaptability, and mutual effort. Furthermore, theorizing how digital transformation can be viewed as collaborative infrastructuring work emphasizes the inevitability of the competing concerns in a digital transformation process. Our findings show that this transformation process is driven by breakdowns of various stakeholders and not only the planning. Thus, indicating that resistance can spur action.

This paper presents how system development organizations navigate competing concerns by responding to breakdowns experienced by many different stakeholders (e.g., consumers and partnering organizations). This paper contributes to answering the overall research question of this thesis by providing a perspective on how, on a structural level, the process of navigating competing concerns in a digital transformation can be viewed as infrastructuring work.

5.3 [P3] COLLABORATING IN DIGITAL TRANSFORMATION

Research questions: How do organizations collaborate in the digital transformation towards sustainability?

This paper was motivated by one of the findings in [P2] that states that *digitalizing through partnering* is a pivotal activity in a digital transformation. In [P2], we describe digitalizing through partnering as sharing and accessing missing resources, i.e., knowledge. Sharing resources and expanding partnerships through collaborative actions is a way for organizations to minimize the risk of failure in their digital transformation journey (Berman, Saul and Marshall, 2014; Hanelt *et al.*, 2021). In [P2], we assert *what* kind of collaboration is essential in a digital transformation towards sustainability, lacking the nuance of *how* this dynamic process unfolds. Furthermore, in my case study, we found that the organizational partners might not know how and why some collaboration works while others fail. This uncertainty is a consequence of the seeming non-linearity and equifinality in the collaborative process (El Sawy and Pereira, 2013). However, using the theory of process multiplicity (Pentland *et al.*, 2020), we could identify the underlying paths and patterns pervasive in this uncertainty. Firstly, we found that inter-organizational collaboration in a digital transformation of district heating can be viewed as a problem-solving process. Focusing on problem-solving has revealed not only what is being transformed (problem) but also how transformation occurs (solution) and why (sustainable development). Lastly, in [P3] er propose that partnering system development organizations productively collaborate in digital transformation by 1) *establishing ownership* of problematic situations, 2) *compromising* on ideal problem-solving, and 3) *setting boundaries* in problem-solving. These processes were persistent in the problem-solving process, however, adapting to the problematic situations in their digital transformation journey. In [P3], we do not encourage extensive planning and negotiating of these processes prior facing unexpected problems. That being said, in [P3], we state that having a unifying goal is beneficial in problem-solving. A unifying goal elevates the discussions and reminds the partnering organizations of their objective — to digitally transform towards environmentally sustainable energy sector.

This paper contributes to answering the overall research question of this thesis by providing insights on how partnering organizations dynamically navigate uncertainties in their digital transformation journey. However, digital transformation towards sustainability can and should have an impact beyond an organization or an inter-organizational context. Therefore, it is vital to understand how this process occurs on a larger scale and scope.

5.4 [P4] FOUR PROCESS VIEWS ON PROBLEM-SOLVING

Research questions: What do we know about the different views on problem-solving in the digital transformation towards sustainability?

[P1], [P2], and [P3] provided an empirical understanding of the competing concerns in a digital transformation of the energy sector in Denmark. [P4] was motivated by my wondering about what we know about competing concerns in the digital transformation towards sustainability in the related literature. This wondering occurred because the literature on digital transformation towards sustainability is varied and characterized by different perspectives on the role of digital technologies in this process. For example, some perceive digital transformation as automating processes to achieve eco-efficiency (Chen, Boudreau, Watson, 2008), while others see it as a means of increasing people's engagement with environmental sustainability (Seidel *et al.*, 2018). This diversity of viewpoints highlights the complexity of the climate change problem and the difficulty of seeing a clear path forward (Introne *et al.*, 2013). Thus, this literature review aims to understand the competing process views in the digital transformation towards sustainability and to uncover the underlying assumptions guiding these perspectives. We analyzed 32 articles and found four competing process views on how digital transformation can further environmentally sustainable development. *Optimization view*: the role of digital technology is to make resources, services, and infrastructures work efficiently and effectively towards sustainability goals [P4]. *Eco-feedback view:* the role of digital technology is to promote behavioral change through consumer data towards sustainability goals [P4]. *Reflection view:* the role of the digital is to challenge the status quo through design towards deliberate practices [P4]. *Participation view:* the role of digital technology is to achieve change through human engagement [P4]. We found that these views differ in their understanding of the problem, the solution, and the assumption of sustainability. Based on this finding, we developed a framework of four process views for recognizing potential disagreements on the role of the digital in sustainable development. This framework pertains to the idea that if underlying assumptions remain unchecked, the IS researchers might not be able to determine when or how to move in new directions (Schein, 1999). Thus, we might not recognize the new paths (Pentland *et al.*, 2020) and how to navigate this problem-solving journey with others.

This paper contributes to the overall research question of this thesis by identifying four competing concerns in navigating a digital transformation journey. [P4] emphasizes that there is not just one way to transform towards sustainability digitally; there are competing views on the problem, solution, and assumption on sustainability.

5.5 [P5] PROCESS VIEWS IN DISTRICT HEATING

Research questions: How do organizations navigate the different process views in the digital transformation towards sustainability?

This paper was motivated by one of the key findings in [P4], which states that there are four competing process views on digital transformation towards sustainable development – Optimization, Eco-feedback, Reflection, and Participation. I wondered how organizations are navigating these process views in practice. Digital transformation towards sustainability is a tortuous journey, and climate change is a wicked problem (Introne *et al.*, 2013); thus, in [P5] we state that there is no clear path that helps organizations navigate sustainable development. Instead, the practitioners must manage problems and solutions that unfold in real-time (as presented in [P3]). However, *how* organizations navigate the four competing process views in practice is unclear. Therefore, we operationalized the framework from the [P4] to analyze multiple performances of problem-solving processes in a digital transformation of district heating in Denmark. In this paper, we illustrate how the digital transformation towards sustainability is a process that can embrace all four process views. Furthermore, as we present in [P5] three propositions on what it implies to navigate competing processes in a digital transformation towards sustainability:

1. *Involvement of multiple stakeholders that reciprocate each other's process views*: In our case of digital transformation towards sustainability, the system development organizations pooled their resources and capabilities into a solution meeting the needs of both organizations and the consumers.
2. *Responding to turbulence in the environment while encompassing multiple process views*: Turbulence is the condition of "unpredictability in the environment because of rapid changes in customer needs, emerging technologies, and competitive actions" (Pavlou and El Sawy, 2010, p. 444) — an example our case study is the turbulence which emerged as a consequence of the consumers' expectations towards what is immediate heating consumption.
3. *Reassessing the past process with different views to adjust the plan of action*: Navigating digital transformation is not a simple sequential process; it is an ongoing reassessment of past process views to adjust the course for the future.

This paper contributes to the overall question of this thesis by illustrating how system development organizations navigate a digital transformation toward sustainability while incorporating all four competing process views. This process is guided by the shared value of an environmentally sustainable future; however, practitioners did not have a single path to follow. Instead, the practitioners are continuously *reciprocating* each other's view on problems, *responding* to turbulence, and *reassessing* their collaborative actions – they are adapting to problematic situations.

5.6 SYNTHESIS OF THE PAPER FINDINGS

The findings from the five papers present an opportunity to appreciate how system development organizations navigate competing concerns in a digital transformation towards sustainability.

Through the longitudinal case study, I found that system development organizations and consumers have competing concerns regarding the digitalization of the energy sector in Aalborg, Denmark. For example, there are competing concerns regarding the actionability of information provided by the system development companies [P1]. Furthermore, I found that the digital transformation of the energy sector in Denmark requires *collaboration* between multiple partnering organizations, e.g., sharing knowledge on how different energy sectors and sharing resources to develop software systems [P2]. While sharing and collaborating, system development organizations *dynamically problem-solve*, e.g., adjusting their problem-solving activities to accommodate the problematic situation [P3]. Furthermore, I have identified four competing process views on how problem-solving in a digital transformation process can unfold: Optimization, Eco-feedback, Reflection, and Participation [P4]. Lastly, in navigating competing concerns in a digital transformation towards sustainability, system development organizations incorporate all four competing process views by continuously *reciprocating* each other's views on problems, *responding* to turbulence, and *reassessing* their collaborative actions [P5].

In reviewing the empirical evidence gathered through a longitudinal study and theoretical insights identified through a developmental literature review, I suggest that navigating competing concerns in a digital transformation is about the *reconciliation* of competing process views. The longitudinal case study shows that practitioners do not *resolve* these competing views - the practitioners learn how to live with tensions by engaging in situated problem-solving.

In the following chapter, I discuss my findings by developing and illustrating the theory of reconciling competing process views in a digital transformation toward sustainability by using the metaphor of "hills overlooking a meadow in a valley." With this theory, I seek to *explain* (Gregor, 2006) how system development organizations navigate the competing concerns in the digital transformation towards sustainability. Lastly, I discuss how my theory of reconciliation informs and supports existing research, present my ideas for future research, and conclude this thesis.

6. DISCUSSION

At the beginning of this thesis, I asked how system development organizations navigate competing concerns in a digital transformation towards sustainability. Through a developmental literature review, I identified four competing process views: Optimization, Eco-feedback, Reflection, and Participation. The identified competing process views nuance four views on problem-solving processes that contribute to the overall digital transformation process towards sustainability. Furthermore, through a longitudinal case study, I found that system development organizations navigate these competing concerns through *reconciliation*.

6.1 RECONCILIATION IN A DIGITAL TRANSFORMATION

Contradictions and competition are inevitable in the research on digital transformation towards a sustainable future - "there are no right or wrong answers, only answers that are better or worse from different points of view" (Introne *et al.*, 2013, p. 45). Through a literature review, I have identified four competing process views - four hills from which researchers observe how the digital transformation towards sustainability can unfold (see Figure 3) - Optimization, Eco-feedback, Reflection, and Participation [P4]. Each process view has forced perspectives on the *problem*, the *solution*, and an underlying *assumption* of sustainability. These competing process views offer alternative explanations for the role of digital technology in solving the wicked problem of climate change. These competing views have not previously been made explicit in the context of digital transformation towards sustainability. The core sustainability problem is to ensure "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland and Khalid, 1987). However, this is not a manageable problem since we have different understandings of how to meet the *needs* of present and future generations. The four competing process views are illustrative examples of different interpretations of needs. These understandings help in narrowing down the wickedness of the climate change problem. However, in narrowing down the climate change problem, we, the researchers, might find ourselves standing on a metaphorical hill overlooking a meadow in a valley through which the practitioners - step by step – shape their digital transformation journey (see Figure 3). Having the high ground provides researchers with an overview, allowing for identifying patterns in this uncertain and complex journey, making sense of the situated problems, and identifying solutions applicable in similar contexts. Thus, by standing on top of a hill, academics can abstract from the daily chaos and help practitioners frame the questions they should be asking (Ross, 2020). This metaphorical hill is built on theoretical, methodological, and philosophical considerations that influence how researchers view a phenomenon.

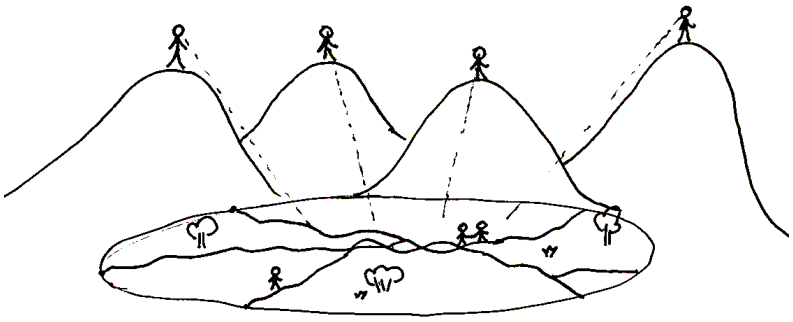

Figure 3 Views (hills) on the digital transformation process (a meadow)

Each hill provides a forced perspective – a view - which influences how the researchers understand the actors' journey across the meadow and how the researchers envision the future actions needed to accomplish this journey. The metaphor of hills emphasizes how the same phenomenon, e.g., a single digital transformation journey, can be perceived differently by researchers.

Furthermore, the hills and a meadow in a valley are all part of the same terrain - the same area of concern – which, in this case, is digital transformation towards sustainability. There are no hills without a valley, and no valley without the hills – they are becoming in relation to each other. Thus, this metaphor also emphasizes the inseparability of theory (hills) and practice (a meadow in a valley). The metaphorical hills can be perceived as the ideal types that do not perfectly reflect reality but are ostensive (Weber, 1949). Even though the ideal types cannot be perfectly replicated in practice, practitioners often approach an ideal type (Negoita, Lapointe, Rivard, 2018). Thus, based on our literature review [P4], I anticipated that practitioners would also have a predominant process view - a fixed point of reference in their journey across a meadow in a valley - which guides them in the moment of doubt. However, my research shows that the practitioners do not have "a hill to die on." The practitioners navigate this meadow by collaborating, engaging with their surroundings, and establishing norms for recognizing and resolving disagreements [P5] – they are *reconciling*. For example, in my case study, Watts A/S has the ambition to transform and disrupt practices in the energy system. They view the disruption as democratizing energy trading by enabling stronger energy communities. On the other hand, Aalborg Forsyning views the digital transformation of district heating as a journey of full automatization and increased involvement of the consumers. Watts A/S and Aalborg Forsyning reconciled these differences by recognizing the possibilities and limitations of their collaborative problem-solving [P3].

Furthermore, they navigated this complexity by continually adapting to problematic situations and reciprocating each other's experiences [P5]. Based on these insights, the illusion of four views – four separate paths viewed from the hills - fell apart in the messiness of practice. However, Watts A/S and Aalborg Forsyning needed a shared direction (sustainable energy consumption) to elevate the discussions and remind them of what they agreed on – namely, the digital transformation towards environmentally sustainable energy consumption [P3]. Thus, the practitioners navigate through the meadow without imposing their views on a possible destination while maintaining a mutual direction.

Based on the empirical evidence, I suggest that the actors in their digital transformation journey are ongoingly *re-viewing* their journey, i.e., the problem, the solution, or the assumption on sustainability. I conceptualize re-viewing as a joint action between multiple actors and involves reflecting on past actions to adapt to their current problematic situation and plan for future action [P5]. For instance, the Watts application provided consumer consumption through monetary value. However, providing consumption through 'the money spent'-function did not engage consumers to act sustainably. Thus, Watts A/S and Aalborg Forsyning were navigating in a direction that did not further sustainable energy consumption. As a result, the two organizations had to reassess the decisions made in the past to identify a new way of providing consumption information that promotes sustainable behavior, e.g., CO_2. Thus, reconciliation is an ongoing process that is influenced by problem-solving activities [P3]. Furthermore, in this ongoing problem-solving, the competing views on a digital transformation can manifest as breakdowns, which drive a two-way digitalization process [P2]. Thus, reconciliation is an ongoing process that is influenced by problem-solving activities.

In summary, the digital transformation towards sustainability is a complex and multifaceted issue with multiple competing concerns. I have identified four competing process views through a literature review; each view offers an alternative explanation for the role of digital technology in solving the wicked problem of climate change. The metaphor of hills and a meadow in a valley highlights the interdependence of theory and practice and how the same journey across a meadow can be perceived differently by researchers. In practice, the actors in the digital transformation journey are continually re-viewing their journey, reflecting on past actions to adapt to current problematic situations and plan for future action. Thus, empirical evidence suggests that actors in a digital transformation journey navigate through the meadow without imposing their views on a possible destination while maintaining a shared direction of sustainable energy consumption. The re-viewing process is a joint action between multiple actors that helps to reconcile differences and align with a common goal.

6.2 RESOLUTION AND RECONCILIATION

> *On the high ground, manageable problems lend themselves to solution through the use of research-based theory and technique. However, in the swampy lowlands, problems are messy and confusing and incapable of technical solution.*
> (Schön, 1995, p.28)

In this quote, Donald Schön illustrates the competing concerns of relevance or rigor. Schön (1995) describes how on the high ground, the problems are lacking in societal relevance while having great technical interest and rigor. On the other hand, relevance can be found in the swampy lowlands where uncertainty, complexity, and indetermination roam. In this description, I recognized my metaphor of hills - high ground - and a meadow in a valley - swampy lowlands. This realization made me wonder whether my theory has a competing concern of its own. In this reflection, I recalled my unsuccessful attempts at achieving a synthesis of the four competing process views. I sought to identify how the four competing process views could be interrelated, interdependent, or transferable to similar contexts – I was searching for a single holistic path through the meadow. The empirical evidence, however, did not support my endeavor; I was looking for rigor in the indeterminate zone of practice, characterized by uncertainty and uniqueness (Schön, 1995). In my attempt to be rigorous, I sought to *resolve* the competing views.

Resolution implies a long-term commitment to ending a tension by identifying a solution that encompasses the needs of both sides "through active engagement in joint problem solving" (Bar-Tal, 2000, p. 112). Active engagement implies appreciating the tensions and discovering a viable long-term solution (e.g., synthesizing two opposing forces - creating a new construct). A long-term solution usually implies a compromise made on a structural level by the policymakers to end unwanted tension (Bar-Tal, 2000, p. 112). However, while *resolving* the tensions by creating a new viable long-term solution, we might undermine each concern's validity and uniqueness (Ross, 2020). Furthermore, a *long-term* solution does not conform to the dynamic nature of the digital (Tilson, Lyytinen, Sørensen, 2021).

On the other hand, reconciliation is an ongoing process (Leiner, 2018) of legitimizing the inevitability of tensions. Reconciliation is a process that occurs when competing parties are engaged in situated problem-solving (the meadow). However, reconciliation implies that competing views will always be there. Only through ongoing adjustments and consideration of mutual needs (Bar-Tal, 2000) can problem solvers learn to live with tensions. That being said, what reconciliation is and how it unfolds is difficult to define outside of the problematic situation – there is no way to establish a future free of conflict - the best we can do is to establish norms for recognizing and living with possible disagreements (Hardimon, 1992). Thus, reconciliation is not about ending tensions but about identifying how the competing

views on a digital transformation can co-exist and how it is possible to establish norms for reconciliation (see Table 3).

	Resolution	**Reconciliation**
What	Ending a tension or a conflict	Living with tension or a conflict
Why	Conflicts and tensions are unwanted	Conflicts and tensions are inescapable
How	Specifying a determinate situation for problem-solving	Exploring an indeterminate situation with problem-solving
When	A viable long-term solution is discovered	Ongoing adjustments are deemed feasible
Where	On a structural level	In addressing a situated problem
Who	Policymakers	Problem solvers

Table 3 Defining resolution and reconciliation, based on (Bar-Tal, 2000)

I suggest that reconciliation is not a synthesis of competing views leading to the creation of something new (Lindgren, Mathiassen, Schultze, 2021; Tilson, Lyytinen, Sørensen, 2021; Stockhinger and Werner, 2022). It is essential to establish that I do not view reconciliation as better than resolution. Resolution is a crucial process that enables conceptual clarity and abstraction, making the solution applicable in similar contexts (Ross, 2020). I agree that the resolution must be identified when it is possible to end tensions. The process of reconciliation, on the other hand, is a process that recognizes the legitimacy of competing forces. Thus, when the ongoing adjustments are deemed feasible, it is vital to recognize competing views on the problem, the solution, or the underlying assumptions about sustainability to facilitate problem-solving in the digital transformation towards sustainability.

6.3 CONTRIBUTION TO RELATED LITERATURE

At the beginning of this thesis, I have outlined how the literature on digital transformation describes this process as complex and dynamic - driven by unforeseen processes and collaborative practices (Ulfsnes *et al.*, 2022; Stockhinger and Werner, 2022). In recognizing that the digital transformation process is fluid and dynamic – a flow – we, the researchers, can begin to view this process as a continuous flow of actions that interact with each other (Ulfsnes *et al.*, 2022). Viewing digital transformation as a flow makes prescriptive and goal-oriented research less applicable in practice. Thus, this literature emphasizes the challenge of planning and executing a digital transformation journey because each managerial action creates a new organizational reality (Lindgren, Mathiassen, Schultze, 2021). The metaphor of hills and a meadow in a valley supports this dynamic view of digital transformation. Each step the practitioners take across the meadow – e.g., each managerial action - reveals

new terrain – a new organizational reality. This process requires new management responses, namely "bracketing the doubt and uncertainty that characterize a tension and letting the tension play out to allow for the emergence of a resolution" (Lindgren, Mathiassen, Schultze, 2021, p. 1206). The idea of letting the uncertainty play out is in line with the notion of reconciliation. However, Lindgren, Mathiassen, and Schultze (2021) state that tensions should play out "to allow for the emergence of a resolution" (p. 1206). Expecting an emergent resolution makes sense when viewing a process from a dialectical perspective (Van De Ven, 2007) – as Lindgren, Mathiassen, and Schultze (2021) do. Furthermore, Lindgren, Mathiassen, and Schultze (2021) were studying technology *standardization*, which implicitly suggests a need for a long-term solution (resolution). However, when digitally transforming towards solving the wicked problem of climate change, the resolution does not always emerge [P5]; this process required ongoing adjustments - reconciliation. The notion of reconciliation complements the view of digital transformation as a process that requires *improvisation* - balancing the freedom and constraints while aligning with the strategic intent (Stockhinger and Werner, 2022). In my case study, the freedom is apparent in the organizational ability to navigate the competing concerns by incorporating all four competing process views. Watts A/S and Aalborg Forsyning were continuously *reciprocating* each other's views on problems, *responding* to turbulence in the digital environment, and *reassessing* their collaborative actions [P5]. The constraints were evident in, e.g., the consumers' expectations towards what is immediate heating consumption. In my case, the strategic intent for both organizations was the digital transformation of the energy sector towards more sustainable energy production and consumption.

Furthermore, based on the theory of reconciling competing process views, I support the call for action, i.e., "going down to the meadow in the valley" to appreciate the terrain as the practitioners experience it. Going to the meadow in the valley could be achieved through engaged scholarship (Van De Ven, 2007), action research (McKay and Marshall, 2001), or action design research (Sein *et al.*, 2011). When calling for actions such as "appreciating the terrain," I purposefully argue for researchers' engagement in becoming stakeholders in situated problem-solving (Ågerfalk, Axelsson, Bergquist, 2022). Engaging with practice can affect how the researchers view their metaphorical hill and the valley – providing a new theoretical and practical insight into how a digital transformation journey towards sustainability can unfold.

7. CONCLUSION

The digital transformation toward sustainability is a complex and often uncertain process. In this thesis, I sought to explain *how system development organizations navigate competing concerns in a digital transformation towards sustainability.* In answering my research question, I have identified four competing process views on digital transformation: Optimization, Eco-feedback, Reflection, and Participation. These views are based on different assumptions about the problem, the solution, and the underlying assumption of environmental sustainability. Based on these insights, I propose a framework for recognizing competing views. Furthermore, through a longitudinal case study, I found that navigating competing concerns in a digital transformation towards sustainability can be described as reconciliation - a process of legitimizing the inevitability of competing forces. I found that practitioners engaged in the digital transformation towards sustainability do not have a single predominant process view that guides their activities. Instead, the practitioners reciprocate and collaborate to navigate their digital transformation journey. I suggest that the reconciliation process is becoming when practitioners are re-viewing and adapting past actions to fit with current problems and plans for the future. The notion of reconciliation emphasizes how in a digital transformation towards solving the problem of climate change, the resolution does not always emerge.

7.1 LIMITATIONS AND FUTURE RESEARCH

Some argue that truth is a daughter of time – I do not claim to present the unequivocal truth through my longitudinal case study. However, I strive towards plausibility, credibility, consistency, and transferability (Gregor, 2006) of my arguments. I sought to ensure the plausibility of my findings by reviewing my arguments in collaboration with my co-authors and the practitioners. The credibility of my arguments stems from my data sources – decision-makers from both organizations and the consumers of district heating. The consistency of my findings was made plausible through my theoretical framework, which has guided my data collection and analysis. However, my thesis is not without limitations; the transferability of my theory to other journeys of digital transformation towards sustainability is yet to be demonstrated. This limitation stems from the small scale and scope of my inquiry. I examined two organizations in Denmark's district heating and how they navigated competing concerns in their digital transformation journey. Therefore, exploring whether my findings are scalable and transferable to other digital transformation journeys towards sustainability would be interesting. Furthermore, I only focus on environmental sustainability. Thus, it would be valuable to examine whether the notion of reconciliation of competing concerns can be transferred to economic and social sustainability.

Furthermore, I believe that it would be beneficial for IS community to understand how to recognize when *resolution* is the answer and when *reconciliation* is the way to go. In gaining this understanding, the researchers and practitioners can focus their managerial and strategic efforts (Lindgren, Mathiassen, Schultze, 2021).

My findings also invite to futher explore whether *re-viewing* transpires differently depending on *what* is being reconciled. For example, re-viewing a problem could be less costly than re-viewing a solution, which implies a higher investment. On the other hand, re-viewing an assumption on sustainability is more expensive than re-viewing a solution because it means a change in fundamental values and, thus, requires even higher investment. In my literature review, I propose a framework for conceptualizing these potentially chaotic collaborative actions and suggest that it could help understand how and what is being reconciled. Our proposition stems from the agile way of thinking that open deliberation about the problem to be solved is a way of reconciling competing views on software development practices (Ananjeva, Persson, Bruun, 2020). Researchers and practitioners may have different assumptions about sustainability in collaborative efforts toward sustainable development. For example, researchers might view sustainability as a radical change in the state of mind (Reflection view) and seek to develop provocative digital artifacts. In contrast, practitioners might view it as a matter of efficiency and effectiveness (Optimization view) and focus on developing efficient digital services and infrastructures. These different views can inform one another and contribute to developing a multifaceted solution [P5]. Still, if the competing views are not explicit, it can potentially lead to misunderstandings and inhibit collaborative efforts.

Lastly, going back to the metaphorical hills and valleys, it would be of interest to IS community to explore how we can reconcile competing views on digital transformation by "building bridges" between the different viewpoints. Building a bridge could imply engaging in interdisciplinary research activities (Brocke *et al.*, 2013). By building bridges between multiple research communities, the IS scholars could challenge their own (or others) forced perspectives on the problem, the solution, or the underlying assumptions on environmental sustainability. By building bridges and exposing ourselves to the insights from other research communities, we could potentially; i) challenge the assumptions about the core aspects of IS research on digital transformation towards sustainability and ii) identify the blind spots in IS research on sustainable development. By building bridges between multiple perspectives, researchers and practitioners can begin to consider the process as a *whole* - presenting the nuances in situated and complex problematic situations.

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APPENDICES

[P#]	Included papers
[P1]	Svangren, M. K., Jensen, L. K., **Ananjeva, A.**, Persson, J. S., Nielsen, P. A., Brunsgaard, C., & Sperling, K. (2020). Investigating One-Time Actions for Domestic Energy Reduction: The Case of District Heating. *In Proceedings of the 11th Nordic Conference on Human-Computer Interaction (NordiCHI'20)*
[P2]	Svangren, M. K., **Ananjeva, A.**, Persson, J. S., Mouritsen, L. K. E., Nielsen, P. A., & Sperling, K. (2021) Infrastructuring in Digital Transformation: An Action Case Study of District Heating. *Twenty-ninth European Conference of Information Systems (ECIS'21)*
[P3]	**Ananjeva, A.**, Persson, J. S. & Nielsen, P. A., (2022) How organizations collaborate in the Digital Transformation towards Sustainability. *Thirtieth European Conference on Information Systems (ECIS'22)*
[P4]	**Ananjeva, A.**, Persson, J. S. & Nielsen, P. A., (2023) Digital Transformation towards Sustainability: Four views on problem-solving in the literature. Submitted to: *Fourteenth Scandinavian Conference on Information Systems (SCIS2023)*
[P5]	**Ananjeva, A**., Persson, J. S. & Nielsen, P. A., (2022) Digital Transformation towards Sustainability: A Case Study of Process Views in District Heating, *The 13th International Conference on Software Business (ICSOB'22)*

[P1] ONE-TIME ACTIONS FOR ENERGY REDUCTION

[P1] **Svangren, M. K., Jensen, L. K., Ananjeva, A., Persson, J. S., Nielsen, P. A., Brunsgaard, C., & Sperling, K. (2020). Investigating One-Time Actions for Domestic Energy Reduction: The Case of District Heating. In Proceedings of the 11th Nordic Conference on Human-Computer Interaction (NordiCHI'20)**

Abstract:

The design of interactive technology meant to change people's behavior to save energy in the home has occupied HCI researchers in the last decades. In this paper, we extend current HCI literature by investigating one-time actions for long-term energy reduction. We report from an empirical study using district heating as a case. District heating is a way of heating houses where hot water is distributed through a network of pipes from energy supplier to individual buildings. We report from interviews with energy suppliers and households interested in reducing their energy consumption and ask why and how people take one-time actions towards reducing their heat consumption. We present our findings in three themes of; energy literacy as enabler of heat reductions, motiva- tion for heat reductions, and technology supporting heat reduction. We further discuss our findings as to how one-time actions for long-term energy reduction can be supported through interactive technology.

Investigating One-Time Actions for Domestic Energy Reduction: The Case of District Heating

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ABSTRACT

The design of interactive technology meant to change people's behavior to save energy in the home has occupied HCI researchers in the last decades. In this paper, we extend current HCI literature by investigating one-time actions for long-term energy reduction. We report from an empirical study using district heating as a case. District heating is a way of heating houses where hot water is distributed through a network of pipes from energy supplier to individual buildings. We report from interviews with energy suppliers and households interested in reducing their energy consumption and ask why and how people take one-time actions towards reducing their heat consumption. We present our findings in three themes of; energy literacy as enabler of heat reductions, motivation for heat reductions, and technology supporting heat reduction. We further discuss our findings as to how one-time actions for long-term energy reduction can be supported through interactive technology.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); Empirical studies in HCI.

KEYWORDS

Sustainability, Long-Term Energy Savings, Domestic Energy Use, District Heating;

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1 INTRODUCTION

HCI research has focused on persuading people to change behavior for example, through eco-feedback technology enabling people to change how and when they use energy [21, 25]. However, the long-term effects on energy consumption of this approach have been questioned for a number of reasons such as failing to acknowledge existing practices [19]. In contrast, efficiency behaviors as suggested by [14, 17], are one-time actions for achieving long-term energy reductions such as investing in smart plugs to control consumption or by renovating buildings to become more energy-efficient overall e.g., adding insulation. Gardner and Stern argue that the energy-saving potential for one-time actions far outweighs the potential of behavior change [17]. As an example of HCI research investigating one-time actions is Hasselqvist et al. [19] who found that interactive technology that informs people on their past energy renovations can have a positive effect on decisions for future investments. However, despite such examples, the majority of HCI studies focus on investigating interactive technology for behavior change rather than one-time actions [14, 19, 35]. As such, we still need systematic studies that provide details on how and why people take one-time actions that lead to long-term energy reductions in people's homes and how interactive technology can facilitate it.

In this paper, we extend the current HCI literature with an empirical understanding of long-term energy reduction through one-time actions using district heating as a case. District heating, which is especially popular in the Nordic countries, consists of a network of

pipes with hot water that can be used to heat up individual buildings, neighborhoods, or towns [28]. Buildings can be served from a centralized plant or a number of distributed heat-producing units. Each building is equipped with space heaters that transfer heat from the water to the air. District heating is especially efficient in cities and requires less maintenance compared to other ways of heating e.g., electric heating [28]. For district heating, one-time action for long-term reductions involves investing in smart technology, for example, intelligent thermostats, improving heat installations (e.g., radiators or thermostats) or renovating the house (e.g., adding more insulation to the walls or changing to energy-efficient windows).

We report from informal meetings and interviews with Danish energy suppliers and focus group interviews with representatives from 7 Danish households with the resources and willingness to renovate their house. We present our findings under three themes. Firstly, findings indicate that energy literacy, that is, knowledge about heat use and the consequences, are important in order to take action. Secondly, important motivational factors are highlighted such as saving money and climate awareness, which guides the choice of one-time actions. Lastly, we highlight technology for reducing consumption and that one-time actions such as building renovations or investing in smart technology are preferred over managing energy use actively. We discuss our findings under two headings with ideas that might inspire future HCI research and design for one-time actions for energy reduction in private households.

2 RELATED WORK

In the next two sections, we will first unfold the HCI literature on technology to facilitate sustainable change. Second, we will unfold HCI research on household heating, which relates to our case of district heating.

2.1 Technology facilitating Sustainable Change

Studying and designing interactive technology to facilitate more sustainable behavior in the home is an ongoing challenge in the HCI research community. For over a decade HCI studies have been engaged in design challenges such as raising awareness on the consumption and reduction of resources and promoting environmentally sustainable behavior [2]. Different consumer sectors have been studied such as electricity (e.g., [5, 10, 25, 26]), transportation (e.g., [4, 40]), water (e.g., [16, 29]), and heat (e.g., [1, 13, 21, 31, 36]).

HCI research has been guided by the concept of persuasive technology [12], focusing on behavioral change through eco-feedback [39]. The theory of eco-feedback is built on an understanding that through becoming aware an individual will be able to adjust their energy consumption accordingly [39]. Through the design of eco-feedback [15], a body of HCI research investigates how to change people's consumption of resources, for example, through art and ambience (e.g., [18, 34]), physical materials (e.g., [18, 32, 41]), or lighting ([24,30]). In recent years HCI research has also complemented eco-feedback with concepts such as forecasting to help people plan and change their behavior (e.g., [23, 25, 33]). However, the long-term effects eco-feedback have been questioned for reasons such as failing to acknowledge that people already have established practices that does not fit with the intended behavior change [19, 37], or assuming that every user has the knowledge and willingness to act [38]. Unless people are willing and capable of changing their behavior, behavior change through eco-feedback is not enough as it relies on people to react rationally [38]. As an example, Hagensby et al. [23], found that people often faced difficulties when a washing machine is only available when electricity is from a sustainable resource. They found that washing is an activity deeply woven into household practicalities, and thus, the willingness to change when to perform to wash is perceived as difficult.

A body of more technical research explores automatization of everyday practices and implementation of intelligent agents such as intelligent heat systems and thermostats [1, 21, 36] and intelligent dashboards [42]. These studies illustrate how an intelligent agent can assist or replace energy-saving practices, thus reducing human intervention. However, research illustrates a lack of human engagement over time in maintaining the systems [21, 36] and exposes trust issues in handing over control to intelligent agents [21]. Further, some studies also highlight the potential for where intelligent agents can support energy-saving behavior. Kjeldskov et al. [25], found that semi-automated practices such as washing and heating can effectively be delegated to intelligent agents, practices that require user presence, such as cooking, cannot.

The majority of HCI research on eco-feedback are focusing on changing behavior [6, 14] such as management (e.g., switching on or off equipment), or curtailment (e.g., reducing temperatures on thermostats). However, an alternative perspective suggests one-time actions (also referred to as efficiency investments [6]) aiming at long-term effects have a higher potential of reducing energy use [8, 17]. One-time actions may cover getting more efficient equipment such as buying a more fuel-efficient car. This is in contrast to changing behavior, which might cover changing practices e.g. taking the bus. However, in HCI, we still see a lack of studies that explore how and why people take one-time actions and how and if such efficiency behavior can be supported through interactive technology.

2.2 Household Heating

The majority of HCI research on interactive technology to support people's use of energy is mostly focusing on electricity use [19]. However, while electricity use is something that households are expected to be in control of (e.g., turning a switch on or off), heating is affected by many factors beyond the control of the individual household, like the energy efficiency of the building itself, which depends on, for instance, the insulation standard and heat system.

Following the discourse on sustainability, we have seen several HCI studies investigating heat preferences in people's homes ([1,21,31,36]). In relation to heating, HCI studies have explored designs of smart systems that learn people's thermal preferences and adjust the thermostats to minimize the experience of a discomfort (e.g., [1, 21, 36]). Hagensby et al. [21] implemented and studied "HeatDial", a control for intelligent household thermostats, and found that people had difficulties mapping preferences to system action. Alper et al. [1], designed and explored a system for automating heating based on user preferences and real-time prices. They found that although the system is intended to receive user input

every once in a while, users tend to configure it once and leave it. Similarly, Snow et al. [36] explored the impact of smart thermostats, that although smart, still occasionally require user configuration. They found that user engagement in these thermostats declines over time. Further, Pink et al. [31] explore heating practices through an app using sensory ethnography as a framework to inform future sustainable design for heating. They found that household heating practices influencing temperature are more complex than interface builders and designers assume.

The above studies explore electrical heating which is an important means of heating in many parts of the world. However, an alternative is district heating which is used in many Nordic countries. District heating is a system of pipes distributing hot water distributed to individual household. Despite this, few HCI studies have investigated district heating as and energy reduction in people's homes and how interactive technology can facilitate it. One example is Hasselqvist et al. [19], who investigated potential designs for energy reduction actions which focuses on housing cooperatives. In outlining requirements for interactive systems supporting one-time actions, they argue that feedback on past investments and reflectivity are meaningful ways of informing a housing cooperative members about the status of the building and based on that, make future investment decisions.

3 STUDY DESIGN

HCI studies have investigated both understanding and designing for energy reductions in people's homes. In this paper, we extend on this body of knowledge by focusing on one-time actions for improving household energy efficiency in contrast to behavior change. We use district heating as a case and ask how and why people take one-time actions that reduce their heat consumption in the long-term (e.g., replacing to more energy efficient equipment or renovating buildings) and how interactive technology can support it.

Our study design is twofold. Firstly, to understand and explore district heating in private households, we conducted meetings and interviews with representatives of regional energy suppliers that is in the process of developing interactive technologies based on data from smart meters. We did this to explore the domain of district heating and to learn about potential one-time actions that people may take. Secondly, we conducted focus group interviews with 7 households interested in investing in a reduction of their heat consumption. In the following sections, we describe, in detail, our study design.

3.1 District Heating in Denmark

As a case for our study, we are investigating one-time actions to reduce energy consumption from district heating in Denmark. District heating, which is especially popular in the Nordic countries, can be described as a network of pipes with pressurized hot water that can be used to heat individual buildings, neighborhoods, or towns [28]. The consumers can be served from a centralized plant or a number of distributed heat-producing units. Inside every house with district heating, a meter is giving feedback – usually in a simple manner displaying aggregated total consumption data along with displaying real-time consumption and temperature levels for the whole household. The meter is usually installed where the pipes enter the building, which in older houses, means out of sight in the basement or a cupboard in the scullery (see Figure 1). Radiators or floor heaters might be found in each room of the household that cools down the supplied water and heats the air around it (see Figure 1). The temperature is regulated on a thermostat on each unit. The cooled water is eventually returned to the plant for reheating. The price consumers pay is calculated based on a combination of how much energy (kWh) is extracted from the water and the flow (m^3) that runs through the system. House owners are not free to choose a supplier of district heating but are bound to the one that manages the physical pipes in the ground. Prices is set by the energy suppliers and can vary greatly. In 2019, the most expensive district heating supplier charged 53.893 DKK yearly for heating a standard house whereas the least expensive supplier charged 7.400 DKK [3].

The government in Denmark is encouraging the suppliers of district heating to move towards more sustainable alternatives to heat the water such as wind, geothermic, or solar-based sources. Towards this end, many district heating providers aim to deliver fully renewable and more efficient heating, since this allows for a lower and greener heat consumption in buildings – a concept that has also been described as 4^{th} generation district heating [28]. Consequently, distributors see a need to bring down consumption in people's homes for them to produce the energy more sustainably. Investments that potentially leads to reduced energy from district heating are switching old equipment with new, buying smart technology such as intelligent thermostats or renovating the house, adding more insulation in the walls, or changing to energy efficient windows.

3.2 Meetings with Energy Suppliers

As part of a project collaboration on energy savings in district heating systems, we initiated our study with informal meetings and formal interviews with representatives from major suppliers of district heating in Denmark. We did this to get further insights into district heating, but also how their customers relate it to their heating and consumption.

Table 1: Overview of participants in informal meetings.

ID	Gender	Job Function
M1	M	Head of development
M2	F	Head of service
M3	M	Lead programmer
M4	F	Head of HR
M5	M	Head of local energy center

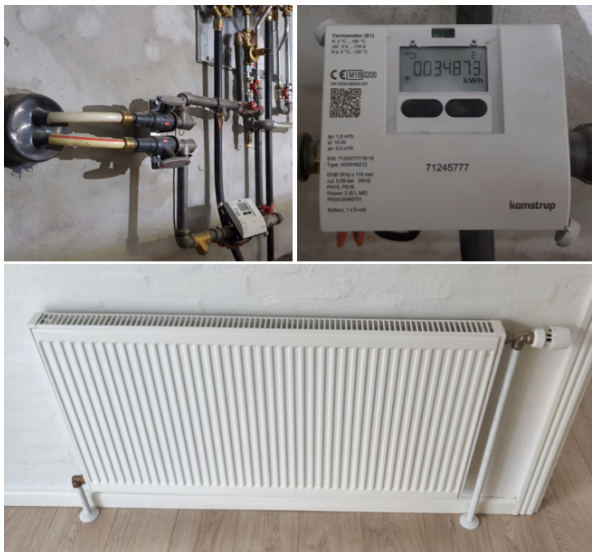

Figure 1: Examples of parts of the district heating system; (top-left) pipes enter and exits a household below ground, (top-right) a consumption meter that displays current and accumulated consumption, and (bottom) a radiator which utilize hot water to heat up the surrounding air.

As part of a collaboration, we participated in ongoing informal meetings with Aalborg Forsyning, which is one of the largest suppliers of district heating in Denmark. Besides providing district heating, they are also subjected to a reduction in consumer energy consumption from the government. Towards this end, they offer services to help their costumers save on their energy consumption and further they are currently implementing an app with heat consumption feedback. The informal meetings consisted of discussions of consumer behavior. Five representatives from the company usually participated in the meetings (an overview of participants can be found in Table 1). The meetings were primarily explorative and thus, we had an informal agenda with topics for discussion that was shared with the participants before the meeting. We gathered data as audio recordings supplemented with researcher notes from each meeting.

We also conducted semi-structured interviews [27] with two representatives from major electricity and heat suppliers in Denmark (see Table 2). These representatives are in charge of implementing and maintaining an energy feedback platform that is currently shared with several different companies, including Aalborg Forsyning as mentioned above. The app has capabilities of gathering information about customer electricity, heat, gas, and water consumption. We conducted interviews with the purpose of gaining insights into consumer information requirements and experiences with changes in behavior. For each interview, we had created an interview-guide based on the outcomes from the informal meetings. Interviews were conducted remotely using Microsoft Teams. Notes and video recordings were gathered as part of the interviews.

Table 2: Overview of interview representatives from energy suppliers.

ID	Gender	Job Function
R1	M	Head of Energy Supply
R2	M	Head of Digital Innovation

3.3 Focus Group Interviews with Households

Based on insights we gathered from energy supplier representants we conducted focus group interviews [27] with seven representatives from households with district heating living in the same geographical area of Aalborg, Denmark. We did this to ensure that they had the same district heating provider and thus, the same prices on heat. All participants were interested in saving on their heat consumption and lived in single-family houses. We wanted participants that potentially faced a long-term investment, and so, we emphasized that they owned a house where no energy investments had been made in the last five years. We recruited households at an information meeting on investments in energy savings organized by a homeowners' association in Aalborg. Through participation

in this meeting, we collected participant contact information. This resulted in 9 potential candidates of which 7 agreed to participate in focus groups. Participants were between 44 and 75 years old (M=57). Table 3 shows an overview of the participants.

Before the interviews, we informed participants on Email that they could bring with them relevant material about their heat consumption if they wanted to share it with the group. This resulted in the sharing of both monthly bills, consumption overviews, and correspondences between suppliers and participants. The purpose of this was that material served as conversation starters and topics of discussion for the interviews. Following the guidelines for focus group interviews in [27], we presented themes for the participants to discuss. We developed these themes with insights from our meetings with the supplier representatives. During the focus group interview, we would bring up a theme, such as "energy reduction" and "environmental concerns", and let participants discuss. We asked follow-up questions based on the question forms (*how, what, where, why*). Two of the authors facilitated the focus group interview. We recorded the focus group interview on video and made extensive researcher notes. A total of six hours of video recordings, two hours of audio, and several pages of researcher notes were gathered.

The empirical data was transcribed, anonymized and coded by two of the authors following the thematic analysis approach in [9]. Firstly, we familiarized ourselves with the data by reading the transcripts several times. We then identified suggestions for codes (e.g., "motivation"). Secondly, we generated codes to interview quotes (e.g., the code "Monetary Reasoning" for the quote "*Well, an investment needs to correspond to how many years I intend to keep living here*"). Thirdly, we searched, generated, and reviewed themes using affinity diagramming, where quotes were reorganized into themes over several iterations. As a final result of this, a set of three themes emerged.

4 FINDINGS

This study aims to understand homeowners' decisions as to how and why they take one-time actions for heat reductions such as energy renovating. All focus group participants were motivated to reduce their consumption. Some had already taken action, and some were interested in learning more on taking one-time actions for long-term reductions. We found different factors impacting how and why this should be done. In the following sections we present our findings in three themes of; *Energy Literacy as Enabler of Heat Reductions, Motivation for Heat Reductions,* and *Technology Supporting Heat Reduction.*

Each theme is initiated by a quote from a representative from the interviewed energy suppliers and elaborated on with findings from focus groups. Participants have been anonymized. We refer to supplier interviews as R1 – R2 (as in Table 2). We refer to focus group participants as P1 - P7 (as in Table 3). Occasionally, we refer to the number of focus group participants behind an observation, for example, (3/7) would mean three out of seven participants.

4.1 Energy Literacy as Enabler of Heat Reductions

> *"If people don't have to use their time on analyzing and not have a fear of their consumption running wild, then they also have the capacity to do something extra"* – **R1**

A representant from the energy suppliers mentioned that the capacity to reduce consumption depends on people's overview of their existing consumption. Throughout the focus groups we found this to be true. Energy literacy, that is, knowledge about consumption, was found to have an impact on decisions for taking action to reduce heat consumption. While we did find a general interest towards heat consumption, we also found that some participants had limited knowledge about how to transform this knowledge to energy reductions. We found that the knowledge about consequences of energy reductions was seen as important aspects for one-time actions. In the following sections we outline participant knowledge on heating in their household and how the lack of knowledge can impact actions for heat reductions.

4.1.1 Individuals knowledge about heating. Our focus group participants had varying knowledge about district heating and their households consumption. Five participants (5/7) had general knowledge about their heat consumption and how to read it on their meter in the basement. These participants also had in common, that they would follow their consumption when the yearly heat bill arrived. Besides the energy bill, they had employed different strategies to keep track on their consumption, for example, **P3**: *"I have a notebook with some columns with a date, in and out temperature, and consumption of electricity and water".* The purpose of such strategies was to ensure that consumption was within the expected limits and not act upon it unless they identified something that surprised them:

> *"Once a year I put in the numbers, and then I notice that gradually as my kids are moving away from home, then my consumption will improve. The amount of money we buy heat for is so low that, in my indolence, I don't want to act upon it unless something goes wrong"* – **P8**

Some participants also discussed surprises in their energy bills like **P4** who found out too late that his consumption had doubled because of a fault in a valve which had led him to closely follow his consumption and keep track of it every month:

> *"Right now, we have a very annoying case open with the energy provider. In the last year, we've used 1600m3, whereas in the year before that we've used 800m3. So that's a doubling [. . .] There's no clear answer why, but the energy provider seems to think it's a faulty valve"* – **P4**

One participant (**P5**) was a novice in knowledge about heat consumption that, because of recent events in the household, had made her in charge of the energy consumption. She would often confuse heat and electricity in the interviews but expressed in the interviews that she wanted to learn more so she could understand how to keep track on consumption, as expressed by **P5**: *"Well, I'm definitely interested in my consumption, I just have to know how to keep track of it".* Another participant (**P1**) were more interested in the consumption because he liked to, in his own words, "nerd" with

Table 3: Overview of focus group participants.

ID	Gender	House Age	Yearly Income (in DKK)	Energy reduction actions (within five years)
P1	M	1967	700.000	Thermostats
P2	M	1933	> 1.100.000	Windows
P3	M	2002	700.000	Thermostats
P4	M	1901	500.000	
P5	F	1977	300.000	
P6	M	1974	500.000	
P7	M	1973	700.000	Insulation

numbers. On his computer, he kept a spreadsheet with consumption. Every time an overview from the energy provider arrived, he inserted the numbers into the spreadsheet to keep it up to date.

Interestingly, we found that some participant requested more supporting technology to follow and act upon their consumption. One theme that came up frequently during the focus group was lack of information to act upon. Besides being hidden away, the data offered by the meter installed in their house was too simple as it only offers data on their current use. The participants also argued that it currently was hard to act upon the monthly overviews from the energy supplier because at the moment of receiving it, it often was too late to act:

> *"It's hard to do something if there's a problem with your installation because when you receive the bill it might be too late and then you have to pay"* – **P4**

As such, in the focus group, questions based on the monthly energy were discussed such as how to reduce their consumption, if they are within budget this year, and what they should invest. Further, some participants (4/7) was also surprised to learn that the amount of money they pay for heat was not as easy to calculate as they thought (it's a combination of energy and flow). An outcome of this discussion was a general consensus of a lack of supportive information and visibility about consumption.

4.1.2 Specific advice as prerequisite for heat reductions. We found that getting specific advice related to participant households was an important prerequisite for reductions. Our focus group participants lived in houses where potential long-term decisions could be taken to save on their heat consumption. Some participants (4/7) had already invested in minor energy renovations for their houses within the last five years. Another participant had made an investment in new windows and extra insulation 10 years ago in relation to a major building renovation:

> *"[. . .] we own a standard house from 1973 that's 160 m2 and we are two people living there. We have 75mm of insulation in the walls, then there's the wooden walls, the vapor barrier, isolation, and an outer brick wall. Then I have installed 400mm of insulation on the attic in one part of the house and 120-150mm in the other. I had new windows installed 10 years ago, I've installed a new bathroom and kitchen and that's what we have done"* - **P7**

Interestingly, when participants discussed why they haven't renovated other parts of their houses we observed that an important aspect of taking action to reduce heat consumption is knowledge and advice about energy use and the consequences on particular actions. One participant had considered more insulation on his addict in connection with another building renovation, but questioned its effects:

> *"I've considered if we should install some more insulation on the attic, not a lot, there's only room for 150mm, because we are installing a new stern façade. But I think there's a little more to it than just putting insulation up there, because otherwise I've just gone ahead and done it, I think"* – **P1**

An aspect of missing knowledge is the lack of specific information available. Several participants expressed that there's plenty of advice and ideas available on what to invest in to achieve reductions. However, such advice is not specific and often contradictory to a particular household's heat system setup. One participant argued that such advice needs to be specific to each household to act upon it:

> *"Completely independent advice that you can trust, what you can do at your place is this and that. And the plumber can say, do this and that with you heat system. Then you don't have to listen to seven different types of advice that are contradicting each other"* – **P7**

Some of the participants (2/7) had also signed up for energy advice offered by the energy company. However, regarding such advice another interesting aspect was trust and the perceived hidden agenda, for example, that renovations could benefit the energy company instead of the costumers.

4.2 Motivation for Heat Reductions

> *"There's almost nothing that is as uninteresting for consumers as their energy consumption"* – **R2**

As expressed by an interview representative their experience was that it was hard to get consumers to save energy because it

does not interest them. We found that participants wanted to learn more about their consumption and that this interest was fueled by specific motivation. Along these lines we questioned participants on motivation and asked them to discuss and elaborate on how they relate it one-time actions for energy reductions in the past. Although our participants had different economical situations (different incomes), all participants mentioned that making a rational choice based savings of their reduced consumption was important. However, all participants also mentioned that ideological motivation such as reducing their carbon footprint was important although secondary. In the following sections, we describe the motivational factors for one-time actions for reductions in heat consumption.

4.2.1 Monetary Reasoning for Reducing Heat Consumption. All participants expressed a general desire to reduce their consumption. Reducing heat expenses was by all participants seen as the primary motivational factor for deciding to reduce consumption. An important practical motivational factor that was debated in the focus groups and was shared by all participates was leveraging an energy-reducing investment with annual heat expenses, i.e., money paid each year to the district heating provider.

Towards this end, all participants argued that return of investment was an important consideration, for example, if investing in additional insulation for the house or new windows would take too long to even out, the investment would not be worth making, for example, **P7** who had already added more insulation to his house stated: *"I've just received an overview from 2018-2019 and we've used 274 m3 and we have paid 9300 DKK for it. That means that it is limited what we can invest in, it needs to pay itself back again.* Additionally, an important consideration for our participants was how long they expected to keep living in their houses:

> *"Well, an investment needs to correspond to how many years I intend to keep living here"* – **P5**

Interesting, we found that the lack of economic benefit for actually taking the final step and investing in reducing their consumption was preventing some participants from making energy reductions. Often a clear overview of how much could be saved for making a specific investment was requested and how it would impact the heat consumption of the household:

> *"The capacity to act would increase if there's specific advice on, for example, if you change the thermostats, then you would be able to save this much money and use so much less in the house. If you put insulation in your attic, then this happens. If you do something with your floors, put some new insulation under there, then this is what happens"* – **P4**

4.2.2 Reducing environmental Impact. All participants mentioned reducing environmental impact as an argument for choosing to reduce energy consumption. Participants debated about climate change and the shift away from non-renewable fuels. Several participants (5/7) argued that climate was a timely and important topic that they considered actively when thinking about investing money in long-term energy reductions:

> "*Now I think climate awareness is much more protruding. We didn't think about things back then [in the '70s] such as climate. Now climate is also part of it besides investments and return of investment. It's like a totally different aspect"* - **P4**

Some participants were considering replacing items in their house because it added little to heating but were more an item of coziness. For example, some participants (3/7) had complementary heat sources such as wood-burning stoves. However, these participants had all considered decommissioning it because it was perceived as something that added little to heating their house but perceived as adding to the climate compared to district heating:

> *"We have considered decommissioning our wood-burning stove. We don't use it that often and it's more an item that adds to coziness rather than heating the house. Our impression is that it's not very clean anyway so that's probably good"* – **P7**

In leveraging reducing consumption based on savings versus environmental several participants mentioned that the latter was not enough alone to make them invest in upgrading their house. First and foremost, participant described that the lack of economic incentives from the government or energy suppliers was important for them to consider taking action. These participants mentioned that the reason they did not invest in their energy efficiency for their house was that they believed that renovating just based on environmental impact was not enough. However, they believed that if people were to actually do something about it, it should be solved through legislation and monetary incentives:

> *"No no, I also think that I would look at the economy in it. I expect that district heating is the most effective because you can heat an entire city with it. But of course, we have a responsibility, but that responsibility should then be regulated through differentiation of how much each household use. I think that's a good idea because then you also place some of the responsibility on the people, that is, that we will try to get as much out of our heat as possible. And then you can always rejoice that those who use wood-burning stoves and such are putting much more CO2 into the atmosphere than the rest of us"* – **P7**

4.3 Technology Supported Heat Reductions

> *"It would take an awful lot from people to adjust their consumption every time energy is clean. We might be naive, but not that much. We don't think that it's something people will adopt on a mass scale, that's why we need some technology to help us"* – **R1**

The energy providers do not expect people to change their consumption based on the availability of energy. The representative argues that technology is needed to help reduce people's energy consumption. We did find that some participants had tried to change behavior like managing their thermostats in their house although unsuccessfully in the long-term. Part of the reason for this was expressed as challenges in the supportive technology aiming to reduce consumption from district heating. Interestingly we found two perspectives on these technologies; occasional adjustment and

upgrading households. We describe these two in the following sections along with the experienced challenges and opportunities as seen by our participants.

4.3.1 Occasional adjusting thermostats for heat reductions. Participants frequently discussed space heater thermostats as something they could manage to reduce their energy bill. However, continuously adjusting the room temperature to match e.g., if the heat was coming from renewable sources, was seen as unrealistic. One participant had tried turning on and off thermostats frequently which made the effects of his actions more noticeable but argued that it takes too much time:

> *"It looks better now that I've tried adjusting frequently. I've calculated what happened if I open a particular thermostat, but I can't keep using my whole life doing that"* - **P2**

In contrast to continuous adjustments, interestingly, we found that reducing consumption by adjusting individual heaters in the household occasionally was already a practice in most households. Adjusting could be done when a room was left empty for some time or switching from summer to winter temperatures. Several participants (5/7) had already formed routines around managing their heat consumption in this way although hard to apply to the whole household:

> *"Usually we leave the heat off in the office, then when we need to go in there, we turn up the temperature. You can't do that for the whole house because we stay there, but the office works fine because we are not in there very often"* – **P4**

However, figuring out how the numbers on the meter relates to a specific device was previewed as hard. Some participants (3/7) expressed that they had tried to figure out the numbers on the meters although without luck. They requested that they could be mapped to specific devices or rooms as a way of supporting thermostat adjustments.

> *"I think it's the delta value I need to look for, but it's hard, because I don't know when I've used. If I could get an overview of how much I've used at give moment I could also do something about it"* – **P2**

Some participants (3/7) argued that they believed that the effects of managing their consumption were negligible in the light of their overall consumption unless it was done consistently throughout the year to have an effect. Although these routines were seen as trying to conserve heating in their house, these participants also saw it as problematic because of no visible effects on their energy bill. Towards this end, several participants mentioned that they often questioned if their actions were correct and if it could be done even smarter for example if reducing heat in a room for some time actually reduced their overall consumption. Towards this end, it was also seen as a challenge that their current meter only provides information about overall household heat consumption and not on device level:

> *"My thought was that if I can get an indicator for if it is good or bad to turn down thermostats during the night like I can with those smart-thermostats then I can lower the temperature in different rooms. Then after a month, you might be able to read on it that you've saved so a so much or that you have the same consumption"*– **P4**

4.3.2 Upgrading households for long-term heat reductions. We observed a general attitude and willingness to cut consumption through upgrading actions such as renovating their household or investing in technology rather than managing through continuously adjusting thermostats.

Some participants (4/7) mentioned that investing in smart technology that perform adjustments was preferred over managing household heat consumption by constantly having to adapt to and relate to information from their heat energy meter. It wasn't perceived as feasible or convenient to follow their consumption by reading off the meter often hidden away in a basement. These participants argued that investing in solutions such as smart-thermostats could be a possible solution that, although not something they wanted to interact with every day, could warn them if their consumption was going in the wrong direction:

> *"My sole motive is to be notified if something is going in the wrong direction, but you won't get me to check an app every hour"* – **P3**

Not all participants were keen on installing technology in their household and argued that they have so much technology around them nowadays that they try to limit the amount in their household, for example, **P7**: "*I don't want to do anything about it and I certainly don't want technology that every day goes beep beep. I have enough of that in my everyday life*". As such, another aspect discussed was building renovation. Some households (3/7) had already invested in renovating their houses to reducing consumption. However, all participants mentioned that had either already done or were thinking about doing renovations in terms of insulation or windows. This was perceived as a more relatable action as it gives a visible result on their energy bill without having to change their indoor temperature or practices.

> *"It makes sense to invest in the overall energy efficiency of the building and if you are renovating that part of the house, why not invest some extra money"* – **P2**

We found that the return of investment was an important consideration for making choices about renovating parts of their household. However, several of our participants also expressed concerns about indoor-climate conditions if deciding to renovate their houses. One challenge is the lack of information about consequences on specific actions have on their household. Because most participants (6/7) lived in older houses prone to things such as moisture because building requirements were less strict when they were built it was also argued that actions such as adding more insulation might lead to unwanted side-effects such as fungus. This could potentially be more costly to fix over time than the up-front cost. Getting specific advice about an action by someone with knowledge about the area was seen as important:

> *"Completely independent advice that you can trust, what you can do at your place is this and that. And the plumber can say, do this and that with you heat system. Then you don't have to listen to seven different types of advice that are contradicting each other"* – **P7**

In relation to specific advice, some participants (3/7) expressed that dialogue or having a conversation is important aspects of receiving such information which also contributes to trust, for example, **P4 stated**: *"if such advice comes from the energy provider, it's also their responsibility to familiarize themselves with my situation [. . .] I would prefer if I can take a tour with a guy that can point and say there, there, and there. That would also make the advice more trustworthy"*. Some participants also discussed the possibility that such advice could come through interactive technology:

> "*If you could get that information [on which parts of his building to renovate] in one way or the other, for example, the phone, it would be great, but the advice needs to be based on my household*" - **P3**

5 DISCUSSION

The findings in this study have contributed to understandings of how and why people take one-time actions towards long-time energy reductions. In relation to district heating, our findings have revealed that participants already had or were considering making one-time actions towards reducing their energy consumption. Further, participants expressed that one-time actions (e.g., bringing down overall consumption by adding insulation to the attic) were preferred over managing their consumption of heat (e.g., turning on or off thermostats). However, our study also indicates challenges such as the lack of relevant information on how and where to invest money in renovating their houses. Our study reveals that opportunities exist for interactive systems that could support them in mitigating some of the challenges associated with one-time actions.

In this section, we discuss our findings against existing literature. We further highlight the implications that these might have for the design and research in interactive systems supporting one-time actions for energy reduction.

5.1 Designing for Behavior Change or One-Time Actions

Froehlich et al. [14] argue that it is critical for designers to understand the behaviors they are designed for. The ongoing discussions about eco-feedback have primarily involved behavior change when presented with certain types of information [14]. However, this approach has been criticized (e.g., [8, 11, 12, 22, 39]), because it relies on people to make rational choices based on eco-feedback. Unless the users are motivated to change their current behavior the practicalities of everyday life may get in the way of acting rationally [38]. Our findings support these results. Although several of our participants had tried acting rationally e.g., frequently turning up and down thermostats, the findings presented in this paper illustrate a general willingness towards less frequent actions instead and avoiding clashing with everyday practicalities. As such, several of our participants were more motivated to make one-time actions, that is, investing in technology or energy renovations. The point of highlighting these findings is not to argue that one-time actions are to be preferred over behavior change. Rather we argue here that they are equally important, and designers and researchers need to focus on both.

Designers also need to consider the differences of people, Following the ideas from Strengers [38], some people are willing to change their behavior and others are not. Based on our findings, the participants in our study primarily fall within the latter description. Despite this, some participants had still tried to manage or curtail their consumption. A challenge, from a designer's perspective, is to accommodate these differences in systems that intend to change behavior or facilitate one-time actions. However, we believe that they are not mutually exclusive, and we see them as complementary and equally important. Our findings show that some data could overlap, and systems could thus utilize the same types of data but for different purposes. For example, systems might both be able to encourage the conservation of energy and be able to give advice on one-time actions thus letting the users decide on which behavior they want to accommodate. For district heating such systems might encourage people to adjust thermostats based on the availability of sustainable energy, but also give advice on how to take action to bring down overall consumption and lasting impact. Further, designers of interactive systems might also try to find a balance between one-time actions and behavioral change. For example, our findings illustrate that occasional change such as seasonal adjustment of thermostats could be considered acceptable by people. On the other hand, people might lose interest over time or simply forget about doing so, as also indicated by Snow et al. [36, 37].

5.2 Linking Energy Literacty to Action

Our findings indicate challenges for people to take one-time actions based on their lack of energy literacy [6, 35]. Having the right knowledge is important to act accordingly, whether this is for bahavior change or one-time action. Like studies before us (e.g., [14, 22, 25]), this study also shows that representing these data in a system is not trivial. A question arises as to how to link energy literacy to action. In a literature study of energy literacy, van den Broek et al. [6] suggest awareness of the costs of the energy bill, energy prices, and the ability to conduct an investment analysis in which the costs of energy-saving investments are compared against the future energy costs. Hasselqvist et al [19] suggest that interactive technology supporting long-term energy reductions should support documentation, reflection, and learning. We believe these to be important types of information and complementing this, we would like to highlight further specific perspectives on linking energy literacy to action in energy reductions.

One-time actions for district heating are considered a financial investment often based on tradeoffs between up-front investments and long-time energy savings. Our participants considered especially financial tradeoff too. As such, for our participants, leveraging the different outcomes is a challenge and acting without the proper knowledge can have severe consequences for the household economy both in the present and in the future. This might influence if an action is taken or not. Supporting these findings, we find the definition of energy literacy from [7] in the context of one-time actions useful "*Whether households are able to make a trade-off between long-term savings from energy efficiency investments and the upfront investments that are required to achieve improvements in energy efficiency*". Consequently, we believe that interactive systems supporting such choices should support householders in making right choice amongst different alternatives and being informed of how to do so (e.g., between long term savings and upfront investments).

It seems that the current technology supporting information about heat consumption is perceived as insufficient to judge between alternative actions. Contemporary technology that enables people to learn the specifics, such as past and future consumption of district heating, were found to lack basic information that enables participants to judge whether or not specific actions might be beneficial or not. This is also supported by the findings of Hasselqvist et al. [19]. The lack of information had made a few of our participants, because of curiosity, experiment with figuring out more detailed data on their consumption. Despite this, for the majority of participants the task of reading off the meter was still seen as a difficult task. We believe that interactive systems should support building energy literacy on district heating through clearly supporting such acts of curiosity. Users should be able to access relevant information in a simpler way for instance by migrating the data to a smartphone application instead of having to access a meter in a basement. Further, designers might draw on inspiration from existing HCI literature on eco-feedback to support people in their questions about their consumption. Interactive technology could support users by allowing them to track down problems in their consumption by increasing the granularity of heat data which be divided into days or even hours instead of months like [22, 25].

Besides building energy literacy, knowledge should be linked to action through energy advice. However, our findings also indicate that current advice is not sufficient for householders to make informed choices for one-time actions. These are often perceived as too general (i.e., they would apply for every household),. Buildings are different and taking general advice about building renovation made participants question whether or not this would have negative consequences, such as bad indoor climate. We believe that advice for such action could arise from a dialogue between energy supplier and householder where each stakeholder (both householder and energy supplier) delivers data. This would also help encourage trust in the advice, which some participants argued could be a problem.

6 CONCLUSIONS

In this paper, we presented an empirical study of one-time actions for reducing energy consumption from district heating. One-time actions in this context should be seen as long-term efficiency investments such as extra insulation, new windows, or smart technology. Through a study with meetings and interviews with local energy suppliers and focus group interviews with 7 household representatives, we identified themes that describe important aspects of one-time actions for energy reduction. Firstly, our findings reveal that energy literacy is an important enabler for taking one-time actions as people need to know when and what to invest in. Secondly, we found that a reduction in energy use is primarily fueled by monetary motivation, but also recently, environmental concerns. Finally, we found that actions had already been taken although participants expressed that current technology is a challenge and they needed more detailed data on their consumption and specific advice about the outcomes of one-time actions.

To inspire future HCI research and design in one-time actions for energy reduction, we discussed two headings of designing for behavior change or one-time actions and linking energy literacy to action. Firstly, we argue that designers also need to consider one-time actions in their systems as these will likely target different people than systems for behavior change. Secondly, we discuss how to link energy literacy to one-time actions, which according to our participants are difficult when lacking information about consumption and advice on which investments are most efficient. As such, we argue that interactive systems should facilitate decisions about financial investments, how people build up energy literacy, and advice tailored to the individual household based on dialogue.

Our study has some limitations. Firstly, the recruited participants were all above 45 years of age and interested in how to learn about their consumption. Secondly, heat use and opinions vary across geographical locations. We realize that this may influence their attitudes towards making one-time actions to reduce their heat consumption and we do not claim that our results can be generalized across a wider population. Consequently, carrying out a similar study in a different location or with different people, might yield different results.

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[P2] INFRASTRUCTURING IN DIGITAL TRANSFORMATION

[P2] **Svangren, M. K., Ananjeva, A., Persson, J. S., Mouritsen, L. K. E., Nielsen, P. A., & Sperling, K. (2021) Infrastructuring in Digital Transformation: An Action Case Study of District Heating.** ***Twenty-ninth European Conference of Information Systems (ECIS'21)***

Abstract:

Digital transformation is reshaping the public sector's provision of the physical, information, and human infrastructures that make a society function. Therefore, we need to understand and help support the infrastructuring that different stakeholders do in a digital transformation to make digital infrastructure work. Against this backdrop, we report a two-year action case study of the digitalization of district-heating infrastructure in a Danish municipality. From our engagement in the development and diffusion of smart metering and a personal energy assistant for 39.830 households, we analyze three defining types of infrastructuring in this digital transformation: 1) Digitalizing heat supply metering, 2) Digitalizing consumers' heating practices, and 3) Digitalizing through partnering. We explain how digital transformation has two-way relationships to the stakeholders' infrastructuring work and breakdowns that make digital infrastructure visible. Finally, drawing upon the extant research, we discuss how our study contributes to the research on digital transformation in the public sector.

INFRASTRUCTURING IN DIGITAL TRANSFORMATION: AN ACTION CASE STUDY OF DISTRICT HEATING

Research Paper

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Abstract

Digital transformation is reshaping the public sector's provision of the physical, information, and human infrastructures that make a society function. Therefore, we need to understand and help support the infrastructuring that different stakeholders do in a digital transformation to make digital infrastructure work. Against this backdrop, we report a two-year action case study of the digitalization of district-heating infrastructure in a Danish municipality. From our engagement in the development and diffusion of smart metering and a personal energy assistant for 39.830 households, we analyze three defining types of infrastructuring in this digital transformation: 1) Digitalizing heat supply metering, 2) Digitalizing consumers' heating practices, and 3) Digitalizing through partnering. We explain how digital transformation has two-way relationships to the stakeholders' infrastructuring work and breakdowns that make digital infrastructure visible. Finally, drawing upon the extant research, we discuss how our study contributes to the research on digital transformation in the public sector.

Keywords: Infrastructuring, Digital Transformation, District Heating, Action Case Study.

1 Introduction

Following the current societal discourse, many public organizations are taking action to reduce their carbon footprint by, for example, transitioning to more sustainable energy forms. In this process, digital transformation is reshaping the way citizens access the public sector and its underlying physical, digital and human infrastructure. Digital transformation is *a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies* (Vial, 2019). A highly topical *entity* in this regard is the infrastructure underlying humans' unsustainable consumption and organizations' promotion of sustainability (Hampton *et al.*, 2013).

For information systems research of digital transformation in the public sector, a topical context is sustainable energy production and consumption. In Denmark, district heating is a widely implemented solution supplying 64% (1.7 million) of Danish households (Danish District Heating Association, 2020). District heating is prevalent in the Nordic countries and can be described as a network of pipes with pressurized hot water used to heat individual buildings, neighborhoods, or towns (Lund *et al.*, 2014). The consumers can be served from a centralized plant or distributed heat-producing units operated by district heating suppliers. Danish district heating is shifting to sustainable and renewable sources such as wind, geothermic, or solar, which constitutes 52% of the produced energy in 2020 (Danish District Heating Association, 2020). Many district heating providers aim to deliver fully renewable heating, but

this demands lower water temperatures in distribution pipes and more efficient heat consumption in buildings. These goals are embraced by the concept of 4th generation district heating (Lund *et al.*, 2014). Towards this concept, the district heating provider in the municipality of Aalborg in Denmark, Aalborg Forsyning, is trying to make consumers engage in and change their heat consumption. This process aligns with digital transformation as it is triggering significant changes to the existing district heating infrastructure by digitalizing former physical aspects such as meters and annual consumption feedback. In this way, digital transformation aligns with 4th generation district heating to engage consumers more in their heat consumption (Hvelplund *et al.*, 2019; Krog *et al.*, 2020).

This paper reports from our two-year action case study with Aalborg Forsyning and its digital transformation of district heating in Aalborg municipality. We use an action case, a mixed approach between action research directed at change and case study research directed at understanding adapted from (Braa and Vidgen, 1999) and (Mathiassen, 2002). To the best of our knowledge, research on digital transformation in the public sector is predominantly case-oriented, descriptive, and retrospective. This orientation is useful in generating theory, developing concepts, and promoting new insights (Walsham, 1995), but it does not promote information systems researchers' engagement in digital transformation. In a Swedish municipality, Bengtsson and Ågerfalk (2011) developed an actor-network configuration for illustrating the complex relationships characterizing digital transformation and sustainable innovation. The actor-network configuration included information systems researchers as change actants in enabling digital transformation (Bengtsson and Ågerfalk, 2011). We similarly argue that information systems researchers can play an essential role in public sector digital transformation.

We seek to understand and improve digital transformation towards 4th generation district heating in Denmark as *infrastructuring*, which describes the ongoing work that sustains infrastructures (Bowker and Leigh Star, 2000; Law, 1994; Pipek and Wulf, 2009). Our focus on infrastructuring processes supplements the platformization process view (Bygstad and Hanseth, 2018) that is often related to digital transformation. Against this backdrop, we address the following research questions: (1) What types of infrastructuring do stakeholders conduct as part of a digital transformation of district heating? (2) What kinds of breakdowns trigger these stakeholders' infrastructuring? In this paper, the central stakeholders in consideration are Aalborg Forsyning, its consumers, and the action case researchers.

The paper is structured as follows: First, we outline the related research on digital transformation, infrastructure, and infrastructuring, followed by our action case study with Aalborg Forsyning and its consumers. In the findings section, we present three types of infrastructuring and their inherent breakdowns experienced in our case. We then discuss how our answers to the research questions and a proposed theory of infrastructuring in digital transformation resulting from and guiding our action case study are contributions to information systems research. Finally, the paper ends with a short conclusion.

2 Related Research

In the following section, we specify the concept of digital transformation using (Vial, 2019) and present examples of digital transformation in the public sector. In Section 2.2, we introduce the notions of infrastructure and infrastructuring and extend the concept of digital transformation as involving infrastructuring work.

2.1 Digital Transformation

The digitalization of the public sector enables digital transformation at a societal level. It can improve the quality of services provided by the public sector to citizens and the quality of life of the affected citizens (Agarwal *et al.*, 2010). The notion of *improvement* is essential and signifies not only an element of change but also a positive impact of digitalization (Vial, 2019). This notion is emphasized in the conceptual definition of digital transformation as *a process that aims to improve an entity by triggering significant change to its properties through combinations of information, computing, communication, and connectivity technologies* (Vial, 2019). Vial (Vial, 2019) identifies improvement as an expected, but not guaranteed, outcome of digital transformation. A digital transformation's scope and scale is a *significant change* or high-level impact, making it different from IT-enabled transformation and

digitalization typically associated with *information, computing, communication, and connectivity technologies* (Vial, 2019).

In the prevalent literature on the digital transformation of public healthcare, its expected outcome is the positive impacts of health information technology in lower mortality rates, improved vaccination rates, and patient safety (Agarwal *et al.*, 2010). Another positive impact of digital transformation is increased stakeholder integration in an otherwise disconnected and heterogeneous healthcare system (Agarwal *et al.*, 2010). This positive impact is supported by (Cordella and Paletti, 2018), who describe digital transformation's ability to enable new relationships and dynamics between multiple stakeholders in the public sector (Cordella and Paletti, 2018). They argue that digital technology can enable public service *co-production* by integrating citizens and public- and private organizations. This co-production is a public sector activity to *produce public services with the support of external resources made available to the public administration by external actors* (Cordella and Paletti, 2018). In e-government research, the integration of multiple stakeholders in digital transformation is an essential activity. This activity can maximize value beyond the economic profit for the stakeholders involved (Rose *et al.*, 2018). Involving multiple stakeholders can, however, generate a conflict of interests, increase citizen expectations, and hinder innovation (Flak and Rose, 2005).

Another challenge for digital transformation is the growing complexity and interconnectivity of digital technology in the public sector, which in some cases, hinders citizen involvement and reduces the benefit (Wunderlich *et al.*, 2019). If citizens do not use public services, these services become irrelevant on a grand scale. For example, to transform German households' adoption of sustainable technologies, understanding consumer values can be useful for positively affecting the national level adoption (Wunderlich *et al.*, 2019). This understanding can be acquired through consumer involvement in digital transformation (Piccinini *et al.*, 2015). However, large scale digital transformation in the public sector also calls for attention to the digital infrastructure.

In this paper, we complement the platformization process view (Bygstad and Hanseth, 2018) that is often related to digital transformation with a focus on infrastructuring that is driven by experienced breakdowns in the infrastructure. We seek to understand and improve digital transformation towards 4th generation district heating in Denmark as infrastructuring, which describes the ongoing work that sustains infrastructures (Bowker and Leigh Star, 2000; Law, 1994; Pipek and Wulf, 2009).

2.2 Infrastructure and Infrastructuring

The concept of infrastructure has been widely adopted in information systems research to conceptualize interconnected systems (rather than stand-alone systems) (Henfridsson and Bygstad, 2013). This research covers different settings, e.g., health, telecom, government, manufacturing, levels of analysis, e.g., group, organization, industry, and society, and technologies, e.g., standards, platforms, and the Internet (Hanseth and Lyytinen, 2004). Understandings of infrastructure in these areas differ (Henfridsson and Bygstad (Henfridsson and Bygstad, 2013). Some see infrastructure as it plays out in the complex interdependencies between socio-technical elements (Braa *et al.*, 2007; Ciborra *et al.*, 2000). Others see infrastructure as networks of human and nonhuman actors (Aanestad and Jensen, 2011; Hanseth and Monteiro, 1997). In this paper, however, our framework builds on Star and Ruhleders definition of infrastructure as relationships between organized practice (Star and Ruhleder, 1996).

Infrastructure is traditionally considered something upon which something else "runs" or "operates", such as a system of railroad tracks on which rail cars run (Star, 1999). In critiquing this consideration, Star and Ruhleder (Star and Ruhleder, 1996) proposed that infrastructure is the often invisible socio-technical structures that are part of the background for other kinds of work (Star, 1999). Building on these notions, (Star and Ruhleder, 1996) propose that infrastructure only becomes infrastructure in relation to *organized practice*. For example, to district heating providers, pipes in the ground, heat pumps, and meters in peoples' homes are infrastructure. For consumers, the infrastructure might consist of the things they interact with daily, that is, thermostats and radiators in their homes. On the other hand, for the developers of smart meters or thermostats, they are not infrastructure, they are topic. (Star and Ruhleder, 1996) further outline nine properties of infrastructure as 1) embedded into other structures, social arrangements, and technologies; 2) Transparent to use in the sense that it invisibly

supports the task at hand; 3) either spatial or temporal – it has reached beyond a single event or on-site practice; 4) learned as part of membership; 5) links with conventions of practice in the sense that it is shaped and being shaped by communities of practice; 6) is embodied into other structures through standards; 7) is built into the installed base; 8) is fixed in modular increments; and 9) becomes visible upon breakdown.

While infrastructure is a useful term to describe various structures that sustain our activities, it does not describe the variety of effort that goes into its integration and the ongoing work required to maintain it (Bossen and Markussen, 2010). In correspondence to the features of infrastructure outlined by (Star and Ruhleder, 1996), the notion of *infrastructuring* as a verb has been suggested to describe the ongoing work that builds and sustains infrastructures (Bowker and Leigh Star, 2000; Law, 1994). Building on the work of (Star and Ruhleder, 1996), Pipek and Wulf (Pipek and Wulf, 2009) defines infrastructuring as the *in-situ design work of tailoring and configuring the infrastructure*. They further argue that infrastructuring can be understood as design and as *a motivated, transformational activity that individuals or groups perform*. Motivated means that every design activity has a goal or at least an intention. Transformational means that it induces a change that is intended to have a longer-lasting effect. Towards this end, (Karasti and Blomberg, 2018) note that no one owns the infrastructure, but rather it is shaped through infrastructuring by many stakeholders e.g., both companies and users. (Bannon and Ehn, 2012) add that infrastructuring is an ongoing process rather than a one-time activity.

Following Pipek and Wulf's work on infrastructuring, it is important to consider the point when infrastructure becomes visible to its users and where in-situ design and in-situ work activities become manifest (Pipek and Wulf, 2009). Most often, infrastructuring is initiated by breakdowns either from the technological side (e.g., the infrastructure actually stops working) or from the users' side (e.g., the infrastructure actually works but is perceived as not working or inadequate to fit users' expectations and needs) (Pipek and Wulf, 2009).

In this paper, we see digital transformation as involving infrastructuring with inherent breakdowns (Star and Ruhleder, 1996). We use the term breakdown, which should be understood as when the infrastructure *breaks* so that it no longer invisibly supports the task at hand either from the technological or user side. We use the term infrastructuring to describe the effort that goes into resolving such breakdowns while simultaneously enabling and facilitating digital transformation.

3 Method

This paper reports from two years of collaboration between practitioners and researchers to understand the digital transformation of district heating provision to private households. We chose the action case approach (Braa and Vidgen, 1999) to address the two research questions in 'what' the infrastructuring and breakdowns by stakeholders are in this case. The action case approach is particularly appropriate as the focus has been on digital transformation towards a more sustainable energy provision and consumption. In this collaboration, we as researchers have been participant-observers partly focusing on understanding the case over time and partly participating in making changes in practice, cf. Figure 1. Figure 1 shows how an action case lies between studies focusing on intervention, as in *action* research, and those focusing on interpretation, as in *case* studies.

Based on this research design, we (1) select and describe a case, (2) describe how we have collected the empirical data, and (3) how we have analyzed the data to arrive at the findings.

To examine the digital transformation of district heating, we have collaborated with the district heating provider in the city of Aalborg in Denmark, Aalborg Forsyning. The city municipality owns Aalborg Forsyning. District heating is the most widespread form of heating in households in Denmark and consists of a network of pipes with pressurized hot water used to heat individual buildings, neighborhoods, or towns (Lund *et al.*, 2014). Aalborg's district heating strategy is to deliver fully renewable and efficient heating, involving lowering of the distributed water temperature. This lower temperature will lead to lower grid losses and support renewable heat sources (sometimes referred to as 4th generation district heating) (Lund *et al.*, 2014, 2018).

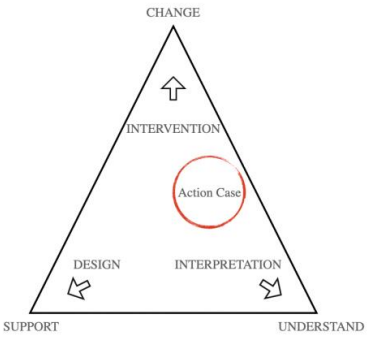

Figure 1: Action case as a mixed approach between action research directed at change and case study research directed at understanding, adapted from (Braa and Vidgen, 1999) *and* (Mathiassen, 2002)

For Aalborg Forsyning to deliver heating with a decreasing carbon footprint and eventually based solely on renewable energy, the consumers must change how they consume heat. This transformation is difficult as it is largely "uninteresting for most consumers". In the digital transformation, Aalborg Forsyning wishes to engage consumers more in understanding and changing their consumption. As a first move in this direction, new smart meters have been installed connecting and sending data every hour to a central data hub. On top of this, Aalborg Forsyning provides consumers with a mobile application, a personal energy assistant named *Watts* informing them about meter readings and budget monitoring.

We collected data from several central stakeholders. Firstly, we participated in a series of meetings over two years (fall 2018 – fall 2020) with Aalborg Forsyning. We took on participant-observers' role in these informal meetings and discussed status and plans for their digital transformation. These meetings served two purposes: (1) appreciating the domain of district heating; and (2) exploring the challenges and solutions facing Aalborg Forsyning in transforming district heating. From Aalborg Forsyning participated five people responsible for the digitalization. From the researchers participated 5-7 researchers from the disciplines of energy planning, sustainable building design, and digitalization. We gathered data in audio recordings, in brief minutes, and researcher notes.

Secondly, we conducted semi-structured interviews with key managers leading the digital transformation. One manager heads the energy supply side, and one heads the digital innovation side. The interviews' purpose was to gain insight into decisions taken, reasons behind, key breakdowns, and proposed solutions. We used interview guides and recorded them through Microsoft Teams.

Thirdly, in the fall of 2019, we conducted focus group interviews with seven consumers before they were equipped with a smart heat meter and had access to their heat data in the Watts app. The focus group interviews were audio-recorded. The focus group interviews addressed expectations and interest in data use of digital metering and prospects of the application Watts as well as interviewees' prior experience with saving energy, e.g., insulation, new windows, and new thermostats.

Fourthly, in the spring and fall of 2020, we conducted semi-structured interviews with 6 consumers after the meters were installed and after they got access to their heating data in the Watts application. The interviews were recorded in MS Teams. The interviews addressed their use of and experience with the Watts application and how that had or could influence their thinking about their heating practices and investing in energy renovation. Findings were continuously discussed with the involved stakeholders to judge and verify their relevance.

We analyzed the empirical data through the following steps:

1. Listen to all recordings, transcribe, then read all transcriptions and other texts to familiarize us with the empirical data.
2. Based on the framework of infrastructure, infrastructuring, and breakdowns, cf. Section 2, critically identify quotes in the data and code these appropriately.
    a. The quotes are selected and coded if they shed light on 'what' or 'why'.
    b. What infrastructuring work are stakeholders doing?
    c. Why are they doing this and what is the breakdown?
3. Link the quotes and codes to the infrastructure, cf. Section 2, to identify how infrastructuring and breakdowns relate to the features of infrastructure.
4. Elicit from this the defining infrastructuring types and structure the network of quotes and codes accordingly.

In the following section, we report our findings of three defining infrastructuring types. Under each type, we analyze the activities that stakeholders (i.e., Aalborg Forsyning, Consumers, and ourselves) do to resolve breakdowns experienced in the digital transformation of district heating infrastructure.

4 Findings

A goal for Aalborg Forsyning is to base its heat production on renewable energy, which the company has already been working on actively for more than ten years. This process has intensified lately with the impending shutdown of the local coal-fired power plant in 2028 which they have, so far, based their heat production on. Aalborg Forsyning has already started to expand the capacity of the physical infrastructure, including expansion into new supply areas. However, consumers' heating practice plays a pivotal role in achieving the goal of sustainable heat production because they are often inefficient (e.g., they use too much heat or do not sufficiently cool the return water), which can lead to potential overinvestments in physical infrastructure (district heating pipe network). Therefore, Aalborg Forsyning is undertaking the project of making consumers use heat more efficiently by engaging them in their consumption through the digital transformation of district heating infrastructure.

In the digital transformation, Aalborg Forsyning and its consumers are conducting infrastructuring in response to breakdowns experienced in digitalizing infrastructure. This section describes the key findings relating to the infrastructuring performed by Aalborg Forsyning in its attempt to make consumers use their heat more efficiently. We present three types of infrastructuring: Digitalizing heat supply metering, digitalizing consumer's heating practices, and digitalizing through partnering.

4.1 Digitalizing Heat Supply Metering

Digitalizing heat supply metering is a type of infrastructuring we found, both, Aalborg Forsyning and its consumers did, driving the digital transformation of district heating infrastructure. This type of infrastructuring included Aalborg Forsyning and its consumers' responses to breakdowns in using supply metering data. Below we describe Aalborg Forsyning and consumer' activities to resolve breakdowns inherent to digitalizing heat supply metering.

The installed base and scope of the district heating infrastructure became visible to Aalborg Forsyning as a limitation towards supplying metering data to consumers. Aalborg Forsyning was digitalizing flow-based heat meters by replacing them with smart meters to get detailed data about consumer heating. An early breakdown for Aalborg Forsyning was the challenge of getting data from individual consumers, which relates to the current installed base of flow-based meters that do not support sufficiently temporal data. When using traditional flow-based meters, the consumer gets feedback on heat consumption annually, while smart meters could provide data on each household's consumption down to the minute. Smart meters' radio transmission of the readings also allowed Aalborg Forsyning to supply its consumers with detailed data about their heat consumption. The shift to smart meters had

also proven difficult. It involved interferences and delays in data as expressed by the head of energy supply in Aalborg Forsyning:

"Our largest challenge, almost from day one, is the delay on the data. Sometimes it's two days, and it's funny, because that's extremely fast compared to what we are used to, but the ordinary consumer for instance is used to looking things up on Facebook instantly and not having to wait days before it gets into the app" – **Head of energy supply, Aalborg Forsyning**

Against this backdrop, Aalborg Forsyning worked on fixing data inconsistencies using existing consumption data, to fill in the missing data. However, after two years of operation, they still faced data inconsistencies, especially in urban areas where a high degree of radio communication interferes with the signals from the digital heat meters.

Responding to Aalborg Forsyning's activities digitalizing heat supply metering, consumers valued the availability of data about consumption. Few consumers knew how to read data from their meter and relied on their annual bill to get an overview. Consumers experienced a breakdown in the limited use of data and knowing how to act on heating data. This breakdown relates to the transparency and embeddedness of the current infrastructure. District heating infrastructure is reliable, and often runs with little involvement from the consumer, and becomes visible only when something goes wrong. For example, John, a consumer and owner of a single-family house with district heating, had an open issue regarding his annual heat bill:

"Right now, we have a very annoying case open with the energy provider. In the last year, we've used 1600m3, whereas in the year before that we've used 800m3. So that's a doubling [...] There's no clear answer why, but the energy provider seems to think it's a faulty valve" – **John, Consumer**

John's heating meter was located in his basement and not easily visible to him, so he did not read it very often as he had trouble climbing down the stairs. As such, he had been unaware of any problems (the temperature in his house was still the same) and had discovered the breakdown too late when the yearly bill arrived. He was unsure how to map the numbers on the meter to any specific part of the heating system in his house and could not solve it. He had contacted Aalborg Forsyning with his issu,e but argued that having metering data in a digital format would allow him to identify a potential problem more quickly because he then could access it digitally.

Before Aalborg Forsyning had completed installing smart meters in consumer homes, we started the collaborative research project by carrying out research activities to help improve its consumers' digitalization experiences. When we entered, Aalborg Forsyning was interested in learning more about their consumers and the potential to change consumer heating behavior beyond the surveys they previously had conducted. We contributed to this process by reporting findings from focus group studies to Aalborg Forsyning published at a Nordic Conference on Human-Computer Interaction (Kvist Svangren *et al.*, 2020) and in an international journal on energy planning (Krog *et al.*, 2020).

In summary, *Digitalizing heat supply metering* is a type of infrastructuring carried out to resolve a breakdown in using flow-based metering data. This breakdown became a reason for replacing the existing infrastructure with smart meters and a reason for digitalizing heat supply metering. On a larger scale, digitalizing heat supply metering helps Aalborg Forsyning and its consumers create a digital infrastructure for digital transformation towards 4th generation district heating in Aalborg. This digital transformation provides Aalborg Forsyning with a vision of efficient and sustainable heating for digitalizing heat supply metering. We intervened in this infrastructuring by helping Aalborg Forsyning understand its consumers' breakdowns in using analog metering data before receiving smart meters. Our investigation also helped Aalborg Forsyning understand its consumers' different visions of efficiency and sustainability for a digital transformation in their district heating.

4.2 Digitalizing Consumers' Heating Practices

The next type of infrastructuring is digitalizing consumer' heating practices responding to breakdowns in informing consumers' heating practices. Below we describe Aalborg Forsyning and consumer activities to resolve breakdowns in changing heating practices.

Aalborg Forsyning was in the middle of implementing several features meant to inform consumers in the personal energy assistant *Watts*, which is a smartphone application visualizing the data provided by smart meters. Towards this end, the current scope and embodied standards of infrastructure providing information to consumers (annual letter with flow-based information) had not proven enough to get consumers interested in changing their consumption practices. As such, finding other ways of informing the consumers about their consumption, by changing scope and standards, was a key activity responding to the breakdown of consumption knowledge and a lack of interest, as expressed by a manager from Aalborg Forsyning:

"For us, the consumers must be a part of this transition, but that is a difficult task. For the past 10 years in Aalborg we have looked into it and found that there's almost nothing as uninteresting for people as energy use in their houses. People want to save money and have a low energy consumption, but getting people engaged in their consumption is just not very sexy. So, the task we have is getting consumers more engaged" – **Head of digital innovation, Aalborg Forsyning**

To address this breakdown, Aalborg Forsyning implemented hourly consumption feedback to give consumers an overview of consumption. However, although consumption feedback was seen as important to increase consumers' knowledge about how much heat they use, it was also a goal to provide a reference point to know if consumption was high or low. Also implemented, was a budget that was calculated from last year's consumption and weather forecast data versus households' current consumption. Furthermore, Aalborg Forsyning had also implemented features to motivate consumers. One feature implemented was an overview of how efficient consumers were in using heat overall, that is, if they in their households are good at cooling the water that is returned to Aalborg Forsyning. Another feature was an alarm function triggered if consumption were beyond regular use.

Responding to Watts's features, most consumers found it interesting that they could be informed about their consumption on their phones instead of waiting for the annual bill, and they felt that they were able to learn about their heating practices. One consumer, Louise, who had been very interested in saving heat from the beginning, explained that she had used the information to lower her consumption. However, the practices built up around the use of the current infrastructure and as such, the set of conventions following it. Several consumers reported that they initially opened the application multiple times a day but that the interest faded over time. As a breakdown, most consumers did not want to follow their consumption closely, they were used to district heating infrastructure he did not frequently have to addend to. They did not see it as a tool to change behavior but more as a preemptive tool where alarms could notify if something went wrong. For example, Peter, a consumer and owner of a single-family house, who was very interested in environmental issues, did not think that he would be able to change his consumption based on information about his consumption alone:

"The amount of money we buy heat for is so low that, in my indolence, I don't want to act upon it unless something goes wrong […] I don't think information about my consumption would change my consumption because I also don't want to be cold. So something else is needed besides that"- **Peter, Consumer**

Practice and conventions go further than information about consumption. Although Peter found the idea of saving heat compelling, he did not find it especially appealing to change his practices based on information about consumption alone and something else was needed. Delving into this, informing to change heat consumption behavior becomes more complex than just consumption information. For example, Peter and several other participants came with additional suggestions of how Watts could inform them to reduce heat consumption. For example, some argued that they would much rather invest

in energy renovations of their houses that could reduce heat consumption overall and that it would be beneficial if Watts also could inform about ways to make such descions. Besides investing in energy investments, Peter and others also reported conventions of practice interfering with the decision on changing heat consumption such as leveraging resources spent on changing heat practices against the cheap price of district heating and a comfortable indoor climate.

After we had been involved in the project for a year, the first consumers had tried Watts and were familiar with its functionalities. Similar to the initial focus groups, we acted as mediators investigating consumer responses and behavior when getting information about consumption through Watts's features through interviews with individual house owners. While our interest was academic, this process also elicited breakdowns happening for, both, Aalborg Forsyning and its consumers. Our results acted as direct input to the company's incremental "trial and error" approach to development. This approach fits well with the feature of infrastructure being fixed in increments rather than at once. Our results were reported and considered for the next iterations. Our involvement continues with a follow-up study on the use of Watts a year after deployment.

In summary, *digitalizing consumers' heating practices* is a type of infrastructuring carried out by Aalborg Forsyning and its consumers to resolve breakdowns in informing heat practices. These breakdowns provided stakeholders with a reason to inform consumers about their heating practices. On a larger scale, digitalizing *consumers' heating practices* helps Aalborg Forsyning and its consumers create a digital infrastructure for digital transformation towards 4th generation district heating in Aalborg. This digital transformation provides Aalborg Forsyning with a vision of efficient and sustainable heating for digitalizing heat supply metering. Our intervention in this infrastructuring through an understanding of consumers' breakdowns in using the application Watts. We also contributed to Aalborg Forsyning's understanding of consumers' willingness and desire to change heating practices as more complex than consumption feedback could resolve.

4.3 Digitalizing through Partnering

A final type of infrastructuring we found was digitalization through partnering. We found actions to resolve breakdowns in accessing knowledge, such as engaging in partnerships to gain the competencies required to digitalize infrastructure. Below we describe Aalborg Forsyning and consumer activities to fix breakdowns in digitalization through partnering.

Aalborg Forsyning has strong expertise in district heating. However, venturing into new areas of expertise about digitalization gave rise to a breakdown related to them being strangers to the knowledge contained within. Having these competencies in-house did not fit Aalborg Forsyning's core business focus on district heating. Instead, their alternative has been to engage in partnerships with other stakeholders who already are experts in their given area gaining knowledge through this collaboration. Examples of such knowledge are installing, configuring, and maintaining smart meters. Towards this end, professionals, such as plumbers, handle installing the district heating infrastructure's smart meters. In calibrating and maintaining and calibrating smart meters a core partner is the leading smart metering provider in Denmark who also delivers smart meters for electricity. They take care of calibrating and gathering data from smart meters and provide the data that keep the Watts application updated.

Access to knowledge about application development was important to enable informing consumers' heat practices. Towards this, a core partner is one of the primary electricity providers in Denmark, who is the primary driver of Watts. Aalborg Forsyning's head of energy supply explained the partnership:

"When we started this, only a handful of similar apps were available on a national plan that could do this. So we could go to one of those companies and ask if we could join. But we did not think the number of users on those apps was particularly good. We thought that we could do better. Then we started with a clean slate and started discussing. We involved a couple of software companies but quickly realized that it would cost millions […] But then, I can't remember who in the group, that talked to someone, that then talked to someone else, you know, we talk a lot across companies. They have heard that

someone in [Electricity company] had received a large bag of money to develop something similar to what we need. Of course, they were not a heating company, but here was the opportunity to create something really cool. So, we engaged in a partnership with them." **- Head of energy supply, Aalborg Forsyning**

To provide their services, the electricity company got more users and feedback on ways to develop the application further, such as user requests. A third partner is the consumers that Aalborg Forsyning supplies with heat. These consumers are co-creators in two ways. Firstly, Aalborg Forsyning has a focus group of consumers that comment on concrete functionality and visual elements in Watts before it goes into production. Secondly, Aalborg Forsyning also receives feedback from consumers for future iterations.

Although not with the sole purpose of saving energy, learning about infrastructure was also important for interested consumers as a part of membership and partnership with Aalborg Forsyning. While only a few found it interesting to actively monitor consumption, several could see the benefit of saving money or getting a better indoor climate. The breakdown for consumers is that it previously had been difficult to access knowledge. Many of the consumers we spoke to, had been informed by Watts, and through that accessed knowledge that had previously been non-transparent to them. Some had used Watts to confirm their current consumption, some were using it as a tool to track their consumption, and others saw the potential to inform if something went wrong in their consumption. Although with slightly different motives (e.g., saving money or achieving a better indoor climate), many of the consumers we interviewed also had an interest to gain further insights into what they could do to use heating more heating efficiently. The consumers participating in focus groups, similarly, saw it as an opportunity to gain insights into the digitalization of district heating.

Our role, as partners of Aalborg Forsyning, has been to support knowledge access about its consumers. For the consumers, our involvement has resulted in accessing knowledge about district heating and their consumption. As researchers, we had an interest in learning about infrastructuring in digital transformation. We experienced a breakdown in accessing knowledge, e.g., cases to study. Partnering has enabled us to understand digital transformation, and we will continue with this practice. We are currently deploying a joint survey of Watts and home renovation, where Aalborg Forsyning helps shape questions through their expertise in district heating and provide access to participants.

In summary, *digitalizing through partnering* is a type of infrastructuring carried out by all stakeholders during this action case study to resolve the breakdown in accessing knowledge. Limited knowledge about digitalization theory-practice has made Aalborg Forsyning, its consumers, and us as researchers engage in partnerships. On a larger scale, digitalizing through partnering helps Aalborg Forsyning and its consumers access knowledge about each other to create a digital infrastructure that helps each part save resources. This digital transformation enables Aalborg Forsyning to meet its vision of efficient and sustainable heating. Our intervention by reporting an understanding of consumers' breakdowns to Aalborg Forsyning helps them to increase consumers' benefit from district heating through digital resolve. As researchers, we have also gained valuable understandings of a digital transformation process towards more sustainable heat provision and consumption through this partnership.

5 Discussion

In an action case study with the Danish district heating supplier Aalborg Forsyning, and its heat consumers, we addressed the research questions: (1) What types of infrastructuring do stakeholders conduct as part of a digital transformation of district heating? and (2) What kinds of breakdowns trigger these stakeholders' infrastructuring? In answering these two questions, we found three defining types of infrastructuring that resolve inherent breakdowns and create a digital infrastructure for a digital transformation towards 4th generation district heating. The first type of infrastructuring is *digitalizing heat supply metering* triggered by Aalborg Forsyning and its consumers' breakdowns in using metering data. The second type is *digitalizing consumers' heating practices* triggered by breakdowns in informing households with diverse and variable heating practices. The third type of infrastructuring is *digitalizing*

through partnering triggered by Aalborg Forsyning and its consumers' breakdowns in accessing knowledge for developing effective digital solutions for district heating.

To make our study and its findings transferable beyond district heating to other digital transformation contexts, we propose a theory to explain infrastructuring in digital transformation. According to Gregor's (2006) taxonomy of theory types in information systems research, this theory is a type II theory that provides explanations but does not aim to predict with any precision. The explanation is a process theory focusing on the dynamics of change instead of variance theories as distinguished in (Van de Ven, 2007).

The notion of infrastructuring provides an alternative view of the work required to achieve digital transformation in the public sector. In this view, digital transformation can be perceived as *a process that aims to improve the infrastructure by triggering significant change to its properties through involving infrastructuring work*. Based on this perception, the digital transformation process consists of dynamic, transformational activities that individuals or groups perform (Pipek and Wulf, 2009). In support of this, our findings emphasize *digitalizing through partnering* as a pivotal infrastructuring activity in digital transformation in the public sector, thus highlighting the collaboration aspect of infrastructuring. Digitalizing through partnering can be perceived as a type of value network in which *complex relationships among multiple stakeholders with potentially competing interests are created for the benefit of customers* (Vial, 2019). However, as presented in Figure 2, consumers are also a part of this value network. Digitalization of district heating towards 4th generation district heating has changed the consumer-supplier relationship, as suggested in other digital transformation research (Piccinini *et al.*, 2015). The consumers became empowered through co-creation activities, while Aalborg Forsyning became more consumer-centered by acquiring feedback directly from the consumers themselves or mediated by us.

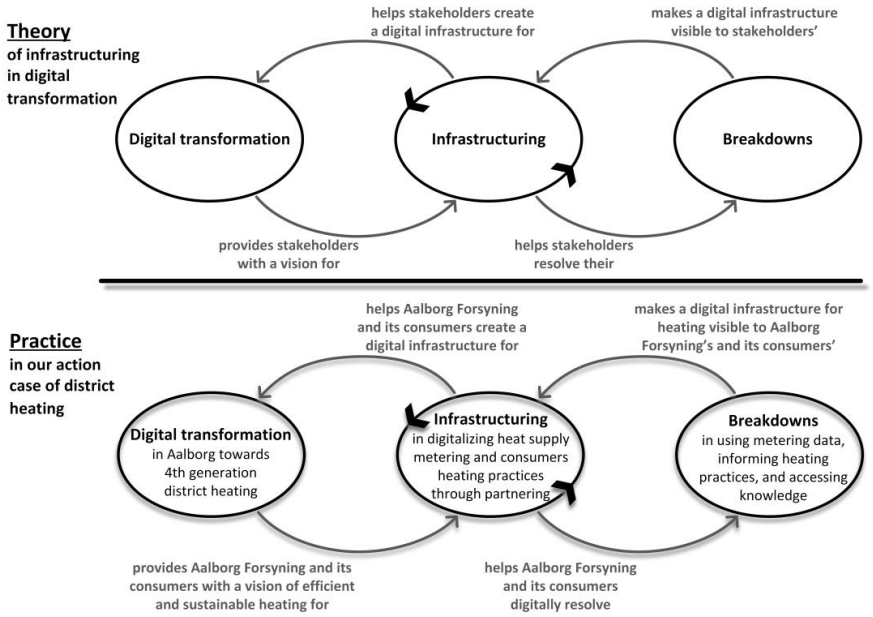

Figure 2: Theory and practice in our action case of infrastructuring in digital transformation

We perceive the two-way relationship between the stakeholders and the transformative activities illustrated in Figure 2 as an emergent characteristic of digital transformation. This view emphasizes the non-sequential properties of the digital transformation process, and it complements the notion of

platformization (Bygstad and Hanseth, 2018). Platformization is the *stepwise* transformation process towards a platform-oriented infrastructure (Bygstad and Hanseth, 2018). However, through active participation, we gained first-hand experiences highlighting the intricacy of the infrastructuring and digital transformation in the public sector. Our findings show that this transformation process is driven by breakdowns to various stakeholders and not only the planning of it. Therefore, we argue that infrastructuring, which is an ongoing and interdependent process rather than a stepwise process, better explains digital transformation in the public sector.

Our argumentation with this action case study has limitations. First, the high level of engagement required to conduct an action case study; some may argue, is not compatible with scientific rigor and limits the study's generalizability (Avison *et al.*, 2018). However, through active participation, we gained first-hand experience with infrastructuring work and its inherent problems (Nielsen and Persson, 2016) that are difficult to obtain through an interpretive case study without an attached form of engaged scholarship (Van de Ven, 2007). Through both interpretation and intervention, we developed a theory that still could be useful beyond the case of district heating. This theory might be transferable to other digital transformation cases in the public sector. We call for future research to examine our theory's explanatory usefulness in other contexts of digital transformation. The theory may help explain the success or failure of digital transformation processes as a complementary view to other understandings in information systems research.

Another limitation is the scope of our research. In our action case study, we were only involved in digital transformation of district heating in a single municipality in Denmark. District heating companies and the municipalities that govern them are diverse. The differences might be related to the economy, size, sustainability initiatives, citizens, and partners, which might affect the digital transformation process in some municipalities. This limitation calls for a collaborative study with other district heating companies and municipalities, to investigate how our theory unfolds on a larger scale. More importantly, we point to a need for such research in other areas of the public sector. Other researchers may look into elaborating aspects of infrastructuring and breakdowns i.e., by focusing on different stakeholders or organizations. Lastly, we also see that further research is needed towards stakeholder values and valuations (Rose *et al.*, 2018) on how they experience breakdowns in infrastructuring, thus bringing forth how stakeholders can provide a vision for digital transformation and vice versa. This research direction may fruitfully complement extensive research on public sector digitalization values (Twizeyimana and Andersson, 2019). More specific directions could be the public sector issues of manager' prioritizations (Rose *et al.*, 2015), strategy (Persson *et al.*, 2017), decision making (Ranerup and Henriksen, 2019), data governance (Benfeldt *et al.*, 2020), and artificial intelligence (Toll *et al.*, 2020).

We further suggest that our theory (c.f. Figure 2) has implications for practice. If a practitioner reads the theory not as a prediction but as a framework that can explain relationships. One may use the framework to ask questions to ponder in the process of digital transformation. It may start in all of the three processes, say in breakdowns. If a breakdown occurs, the infrastructuring that could resolve it may reflectively be taken as an opportunity to modify and evolve the digital infrastructure. If, on the other hand, a digital infrastructure contains a vision, one may ponder about which infrastructuring this will raise or what infrastructuring may well be necessary. That, in turn, may lead to thinking about which breakdowns to expect. From this, we suggest that the theory's simplicity has the advantage that it can be a practical instrument.

6 Conclusions

This paper proposes an understanding of digital transformation as infrastructuring based on a two-year action case study of a district heating provider and their ongoing work to make consumers engage in and change their consumption to better support sustainable and renewable heating sources. This work was part of a digital transformation with significant changes to the existing district heating infrastructure by digitalizing former physical aspects such as meters and annual consumption feedback. Through

informal meetings, focus groups, and interviews with the district heating provider and its consumers, we elicit three defining types of infrastructuring with inherent breakdowns in the district heating infrastructure.

The first type of infrastructuring was *digitalizing heat supply metering*, triggered by breakdowns in the district heating supplier and its consumers' experiences using metering data. The second type was *digitalizing consumers' heating practices*, triggered by breakdowns in informing households with diverse and variable heating practices. The third type of infrastructuring was *digitalizing through partnering*, triggered by breakdowns in accessing knowledge for developing effective digital solutions for district heating.

Our action case study proposes a theory explaining infrastructuring in digital transformation as two-way relationships between digital transformation, infrastructuring, and breakdowns. First, we propose that infrastructuring helps stakeholders resolve their breakdowns and that these breakdowns make a digital infrastructure visible to stakeholders' infrastructuring. Second, we propose that infrastructuring helps stakeholders create a digital infrastructure for digital transformation and that digital transformation provides stakeholders with a vision for infrastructuring. Following this line of thought, we argue that our theory complements other views on digital transformation (e.g., platformatization). We further suggest that our theory can help practitioners and researchers explain a digital transformation in other contexts for purposes of both understanding and change.

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[P3] COLLABORATING IN DIGITAL TRANSFORMATION

[P3] **Ananjeva, A., Persson, J. S. & Nielsen, P. A., (2022) How organizations collaborate in the Digital Transformation towards Sustainability.** ***Thirtieth European Conference on Information Systems (ECIS'22)***

Abstract:

Digital transformation is already changing and improving our society towards sustainable development. However, this process is complex and often requires collaborative efforts between organizations. To better understand how organizations collaborate in the digital transformation towards sustainability, we present a case study of digital transformation in Denmark's district heating. Using the theory of Process Multiplicity that explains how a single process can potentially unfold in many ways, we report how private and public companies have collaborated over two years in their digital transformation. Our analysis identifies three processes that explain how these organizations successfully collaborate by 1) establishing ownership of problematic situations, 2) compromising on ideal problem-solving, and 3) setting boundaries in problem-solving. We conclude the paper by discussing how unfolding the collaboration between organizations can nuance our understanding of collaboration in digital transformation in IS research.

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How organizations collaborate in the Digital Transformation towards Sustainability

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HOW ORGANIZATIONS COLLABORATE IN THE DIGITAL TRANSFORMATION TOWARDS SUSTAINABILITY

Research Paper

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Abstract

Digital transformation is already changing and improving our society towards sustainable development. However, this process is complex and often requires collaborative efforts between organizations. To better understand how organizations collaborate in the digital transformation towards sustainability, we present a case study of digital transformation in Denmark's district heating. Using the theory of Process Multiplicity that explains how a single process can potentially unfold in many ways, we report how private and public companies have collaborated over two years in their digital transformation. Our analysis identifies three processes that explain how these organizations successfully collaborate by 1) establishing ownership of problematic situations, 2) compromising on ideal problem-solving, and 3) setting boundaries in problem-solving. We conclude the paper by discussing how unfolding the collaboration between organizations can nuance our understanding of collaboration in digital transformation in IS research.

Keywords: Digital Transformation, Problem-solving, Sustainability, Process Multiplicity

1 Introduction

Digital transformation towards sustainability is already here – our society is ongoingly changing and improving through a combination of innovative technologies, new business models, and an increased focus on sustainability initiatives within organizations (von Kutzschenbach and Daub, 2021). That being said, it is a complex process that requires considerable effort to succeed. Organizations need knowledge on environmental, economic, and social sustainability as well as the development of innovative technology, rapidly changing markets, multiple implementation domains, and customers. Holding on to the idea that a single organization can encompass all of this knowledge might be an act of hubris since that requires many resources – it is expensive, rigid, and may result in failure (Chesbrough, Henry William, 2003). So, to share the effort and minimize the risk of failure, organizations open up to external influences and expand their partnerships through collaborative actions, including co-creation and co-development (Berman and Marshall, 2014). However, in opening up to external influences, the organizational boundaries become ambiguous – almost porous – introducing new ways of collaborating (Chesbrough, 2003). These new ways of collaborating are called *ecosystems* (Tan *et al.*, 2015) or *networks* (Vial, 2019) and are paramount for the success of digital transformation towards sustainability (Svangren *et al.*, 2021). In furthering this view, digital transformation can involve human infrastructuring work, where *digitalizing through partnering* is a pivotal underlying process towards sustainability (Svangren *et al.*, 2021). Digitalizing through partnering is described as a process of sharing and accessing missing resources, i.e., knowledge, which is in accordance with research on collaboration in digital transformation (Berman and Marshall, 2014; Hanelt *et al.*, 2021). That being said, Svangren *et al.* (2021) only assert *what* kind of collaboration is important in a digital transformation towards sustainability, lacking the nuance on *how* this dynamic process unfolds.

For this purpose, organizations already part of an ecosystem or a network are ideal for studying how they collaborate in practice. Against this backdrop, we present our research question:

How do organizations collaborate in a digital transformation towards sustainability?

To answer our research question, we conducted a single-case study (Yin, 2009) of digital transformation towards the 4th generation district heating in Denmark (Lund *et al.*, 2014). In this case study, we followed how two organizations – Aalborg Forsyning and Watts A/S – collaborate in their digital transformation towards sustainable heating consumption. Using the theory of Process Multiplicity (Pentland *et al.*, 2020), we identified how the two organizations perform their collaboration, which gave us insights into actions and relations that form the collaborative process. These insights helped us unravel how organizations can collaborate in the digital transformation towards sustainability.

2 Related Research

In the following, we introduce related literature on collaboration in digital transformation, highlighting selected research in this area of IS research. Then, in section 2.2, we present the theory of Process Multiplicity – focusing on its' key theoretical concepts - and explain how we can apply it to unveil organizational collaboration in the digital transformation towards sustainability.

2.1 Collaborating in Digital Transformation

Literature concerned with the digital transformation process explores how existing companies transform themselves to succeed in the emerging digital world (Nambisan, Wright, Feldman, 2019). However, the success of the digital transformation is not trivial, and if not competently managed, this process may fail in delivering the intended digital services (Hafseld, Hussein, Rauzy, 2022). The digital transformation process often implies changes to business models, digital infrastructures, potential value propositions (Ross, Beath, Mocker, 2019), and embracing new ways of collaborating (El Sawy and Pereira, 2013; Kopalle, Kumar, Subramaniam, 2020; Hietala *et al.*, 2021). These new ways of collaborating – networks or ecosystems – require further changes in organizational structures and processes (Hanelt *et al.*, 2021). Examples of the necessary changes are: establishing cross-functional teams (Dürr *et al.*, 2017; Ross, Beath, Mocker, 2019), involving customers in becoming value co-creators (Piccini, Gregory, Kolbe, 2015; Carroll *et al.*, 2021) or establishing strategic partnerships with external organizations (Bitran, Gurumurthi, Sam, 2007). These organizational structures and processes changes help support collaborative knowledge flows within and across organizational boundaries (Chesbrough, Henry and Bogers, 2014). Thus, in establishing these cross-organizational knowledge flows, the organizations in digital transformation become a part of *digital business ecosystems* – business environments shaped by a network of interdependencies enabled through digital technologies (Kopalle, Kumar, Subramaniam, 2020, p. 115). These business environments are turbulent and fast-paced due to rapidly changing markets, customer expectations, and emerging digital technologies (El Sawy and Pereira, 2013). This turbulent environment makes it challenging to maintain stable roles, activities, actors, and relations that characterize a regular business ecosystem (Adner, 2017; Hanelt *et al.*, 2021, p. 1171), resulting in non-linearity and equifinality in the collaborative process. The literature on digital transformation has a rich understanding of *what* collaboration characterizes digital transformation. Yet, the literature falls short in describing *how* this dynamic process unfolds. Hanelt et al. (2021) proposed that digital business ecosystems can be understood using configuration theory (Meyer, Tsui, Hinings, 1993) to identify logical structures of change. We, however, present the theory of Process Multiplicity (Pentland *et al.*, 2020) to capture the underlying processes of *how* organizations collaborate in the digital transformation towards sustainability.

2.2 Process Multiplicity

Process Multiplicity is defined as a duality of 'one' and 'many' (Pentland *et al.*, 2020) – a single process can potentially unfold in many ways. A *process* is defined as a set of sequentially related actions that

unfold over time. It is important to note that actions, which constitute a process, are not self-contained entities – they are becoming in relation to others' actions (Feldman, 2016). To illustrate Process Multiplicity and present its' theoretical concepts (see Table 1.), Pentland *et al.* (2020) successfully use a metaphor of crossing a meadow. Potentially, there are many ways to cross a meadow (the notion of equifinality). When a person walks across a meadow, they perform one specific enactment of how this process could unfold (performance). When the process of crossing a meadow is repeatedly performed, paths are being formed (pattering). Yet, Pentland *et al.* (2020) argue that people are prone to follow the existing paths; thus, paths are a dynamic product of the performances and potentially guide future performances (reinforcing the paths). Finally, the complete set of ways a person could cross a meadow is defined as a space of possible paths.

Theoretical concept	Definition
Process	A set of sequentially related actions that unfold over time
Path	A sequence of actions of how a process could unfold
Performance	One specific enactment of a specific path
Pattering	The process of forming and reinforcing paths through repeated performance
Space of possible paths	The complete set of ways a process could be performed based on the observed data
Action	What people do or say
Relation	An empirically observable sequence of two actions

Table 1. Key theoretical concepts in Process Multiplicity theory (Pentland et al.*, 2020)*

These theoretical concepts help explain Process Multiplicity and operationalize it, presenting clear distinctions between complex phenomena and providing focus. In this paper, we focused on the performances (Mahringer and Pentland, 2020) of collaboration between organizations. In examining how organizations perform collaborative processes, it is possible to appreciate how the underlying processes shape and reshape, weaving the fabric of organizational collaboration in the digital transformation towards sustainability.

3 Method

In this paper, we study the collaboration between two organizations – Aalborg Forsyning and Watts A/S. Aalborg Forsyning is a utility company that provides district heating to the municipality of Aalborg in Denmark. Over the last decade, Aalborg Forsyning has been working towards producing heat based on renewable energy. Aalborg Forsyning initiated this process due to the forthcoming shutdown of the local coal-fired power plant in 2028, which is currently producing heat. In anticipation of future changes, Aalborg Forsyning wants to digitally transform district heating to engage consumers and make them use heat more efficiently through information technology. Therefore, Aalborg Forsyning partnered with Watts A/S – an electricity provider and a developer of an energy assistant application – *Watts*. This application provides hourly consumption data on heat, water, and electricity. The overall purpose of the Watts applications is to inform consumers about their consumption and, based on this, potentially change their behavior towards more sustainable energy consumption. The two organizations are a part of a more extensive partnership that works together towards sustainable development in the energy sector in Denmark. At the core, the partnership consists of Watts A/S, Aalborg Forsyning, and Helsingør Forsyning. Other utility companies are also a part of the journey; however, their physical and digital infrastructures do not fully support the Watts application (e.g., installing smart meters). Andel (parent company of Watts A/S) is now primarily active as part of the board of directors, mainly having strategic influence. We have followed the collaboration between Aalborg Forsyning and Watts A/S over the past two years. We saw how their partnering has developed and evolved – it stood the test of time, only strengthening over the years. Due to this persistence, we find this collaboration interesting to unravel as an example of how two organizations collaborate in the digital transformation towards sustainability.

While following how the two organizations collaborate, we noticed that the two companies usually collaborate to solve problematic situations. Therefore, to unveil how Aalborg Forsyning and Watts A/S collaborate, we conducted an embedded single case study (Yin, 2009) of problem-solving processes. The units of analysis were single performances of problem-solving. One way of capturing performances is through narrative (Pentland, 1999). Therefore, in our inquiry into problem-solving, we conducted narrative interviewing (Jovchelovitch and Bauer, 2000) with several relevant stakeholders from both organizations over two years (see Table 2).

Data collection	Stakeholders
10 semi-structured narrative interviews with Watts A/S	• Pod Owner responsible for R&D • Pod Owner responsible for partnering with Utility companies • CEO responsible for the vision for Watts A/S
8 semi-structured narrative interviews with Aalborg Forsyning	• Project Manager responsible for Watts application roll-out • IT-Project Manager responsible for digital infrastructure • Energy Supply Manager responsible for the vision of the digital transformation of district heating.

Table 2. Data collection activities

In this study focusing on the problem-solving process, we recognize the relevant stakeholders as organizational employees that have a *decisive role* in the problem-solving process. Based on this criterion, we bring forth the interviews with the CEO at Watts A/S, Pod Owner from Watts A/S – responsible for partnering with utility companies – and Project Manager from Aalborg Forsyning – accountable for the partnering with Watts A/S. The interviews' purpose was to gather narratives – problem-solving stories – to gain insight into actions and relations that establish collaboration performances between the two organizations. We used interview guides and recorded the interviews through online interviews. Finally, findings were presented and discussed with the involved stakeholders to verify their relevance.

Theoretical concept	Operalization	Definition
Process	Thread	A set of sequentially related actions that unfold over time
Path	Path	A sequence of actions of how a process could unfold
Performance	Narrative	One specific enactment of a specific path
Pattering	Change in paths	The process of forming and reinforcing paths through repeated performance
Space of possible paths	Number of possible paths	The complete set of ways a process could be performed based on the observed data
Action	Node	What people do or say
Relation	Arrow	An empirically observable sequence of two actions

Table 3. Process Multiplicity concepts in our analysis (adopted from (Pentland et al.*, 2020))*

Based on the collected data, we present two narratives that encapsulate two performances of collaborative problem-solving in a digital transformation. We analyzed these two illustrative narratives of problem-solving between the two organizations through the following steps:

1) Listen to all recordings, transcribe, and read the transcriptions to familiarize yourself with the empirical data.
2) Critically identify quotes in the data and code these appropriately in relation to the theory of Process Multiplicity (see Table 3).

   a. Based on the theory of Process Multiplicity, search for actions – sayings and doings – to identify problem-solving narratives.
   b. Combine the narratives into two coherent problem-solving performances.
3) Using abductive reasoning (Brinkmann, 2014) and guided by *astonishments*, we elicit the underlying processes that illustrate how organizations can collaborate in the digital transformation.

4 Findings

This section presents how Watts A/S and Aalborg Forsyning collaborate in their digital transformation with two narrative performances of how the two organizations problem-solve. These narratives are reconstructed sequences, single performances, in a multiplicity of problem-solving processes. The two narrative performances unveil the three underlying processes that characterize collaboration between the two companies: 1) Establishing ownership of a problematic situation, 2) Compromising on the ideal problem-solving, and lastly, 3) Setting boundaries in problem-solving.

4.1 The first narrative of a collaborative problem-solving performance

The first narrative of a performance regards collaborative problem-solving between Aalborg Forsyning, Watts A/S, and Helsingør Forsyning. Helsingør Forsyning is an exciting partner for Watts A/S; as a utility company, they are unusual because they supply their consumers with water, heat, and electricity. This distinction allows Helsingør to have a stronger connection to their consumers, a broader overview of their market, and more data points, which is particularly valuable for Watts A/S. Furthermore, Watts A/S gained knowledge of all three domains (water, heat, and electricity) while working with the same partner to understand these domains more effectively. Helsingør Forsyning shared the vision regarding digitalization and sustainability and had the physical and digital infrastructure supporting the Watts application's implementation. However, the success of the Watts application (the growing number of active users) made it a valuable technology for Watts A/S board of directors. They saw an opportunity to commercialize the application – Watts A/S was told to advertise and sell electricity through the Watts application. This decision resulted in a direct conflict of interest between Watts A/S and the Helsingør utility company.

But then it happened that our board of directors forced us to sell electricity. And so does Helsingør. Suddenly, Watts is a platform where we sell electricity. And it does not harmonize that Helsingør must attract their customers over to the Watts application. We are suddenly competitors – **Pod Owner, Watts A/S**

This problematic situation is interesting because it was unanticipated and involved multiple problem stakeholders. Watts A/S had never imagined selling electricity when the partnership was established. This situation illustrates that the problems that negatively affect a partnership do not solely derive from the partners themselves but can emerge unexpectedly from the dynamic environment in which this partnership was established. Aalborg Forsyning entered this problematic situation when they became aware of the possible cost of this issue. Firstly, the price was losing a partner; secondly, the problem has "occupied Watts A/S resources. And it has had an impact on how quickly changes could be made that everyone was calling for" (Project Manager, Aalborg).

Thus, even though the problem did not directly affect the relationship between Watts A/S and Aalborg, solving the problem did. Therefore, Aalborg Forsyning was a mediator in this story, reminding the other partners of the shared goal to digitally transform the energy sector towards sustainability. Watts A/S presented their commitment to solving this problem to the board of directors, deciding to rethink the marketing strategies and remove the direct advertisement for Helsingør. This problem-solving became a process of learning from previous mistakes.

The problem was solved to avoid the problematic situation and prevent losing potential partners in the future. The concern for the future also seems to be the primary motivator for Aalborg, in their case, a lack of resources to solve other issues that would affect them directly. Yet, if the motivation for the

problem-solving process was directed at the future, the inspiration for solving the problem originated from the past. The past in this problem-solving regarded the expectations towards each partner and the shared goal of digitally transforming the energy sector towards sustainable energy consumption.

4.2 The second narrative of a collaborative problem-solving performance

The second narrative of a performance regards the collaborative problem-solving between Aalborg Forsyning and Watts A/S. In the partnering between the two organizations, Aalborg Forsyning is primarily involved in developing the Watts application for district heating. They are an active partner, highly invested in making this digital transformation succeed. Aalborg Forsyning is a public organization pressured by policymakers and other regulations to reduce its CO^2 emissions and produce heat based on renewable energy. However, district heating is challenging to transform. First of all, the existing infrastructure (network of pipes carrying heated water) is fixed and expensive to change. Second, the consumers are hard to engage in heat consumption. Therefore, Aalborg Forsyning and Watts A/S undertook the project of engaging the consumers in their consumption through the Watts application.

We can optimize the district heating network, make life better for the citizens, and make the network much greener – it will be able to run on much greener energy. So there are a lot of positive domino effects we can put into play by just being together about solving these tasks – **CEO, Watts A/S**

The second narrative performance regards the problematic situation of visualizing district heating in the Watts application. This problematic situation might be perceived as small compared to the suspense in the first narrative. However, both organizations were highly engaged in this collaborative problem-solving to visualize district heating in a meaningful way for the consumers.

This excessive attention to detail stems from the shared understanding that even the tiny elements can impact consumer engagement; both Aalborg Forsyning and Watts A/S did not want to leave it to chance. Aalborg Forsyning hired an external organization to conduct consumer research to understand consumers' perceptions of district heating. Alborg Forsyning later applied the insights in deliberative workshops with Watts A/S, where employees from both organizations met to design, argue, and listen. All stakeholders could then present their point of view; it did not matter which organization they came from before they entered the problem-solving process. They were equal in this problem-solving. After several workshops, they agreed on a design solution that satisfied all parties involved.

This problem-solving process was about establishing a shared view of district heating and determining how this shared view can be represented in the Watts application. When both organizations agreed on the solution to this problematic situation, the shared view of district heating became materialized. Thus, the solution to this problematic situation is a symbol of district heating and an expression of this collaborative problem-solving performance.

4.3 Process threads in collaborative problem-solving

The two narrative performances unveil three underlying processes that characterize the collaborative problem-solving between Aalborg Forsyning and Watts A/S (see Figure 1.).The first process is establishing ownership of a problematic situation (yellow thread in Figure 1.). The second process is compromising on the ideal problem-solving (green thread in Figure 1.). Lastly, the third process is setting boundaries in problem-solving (red thread in Figure 1.). The arrows in the figure represent relations between the actions in a process thread. These processes are pervasive in the collaborative problem-solving between the two companies, even though the two identified narrative performances are distinct from each other. We use a metaphor of threads to describe how these three processes seamlessly emanate and adapt to the problematic situation, weaving the fabric of collaborative problem-solving in the digital transformation towards sustainability. In the following sections, we present the three processes. These process threads are distinct but interrelated. The interrelatedness is evident in the

shared sequences of action. We will not delve into all actions described in the model but make cuts where it is most useful to explain the processes as clearly as possible.

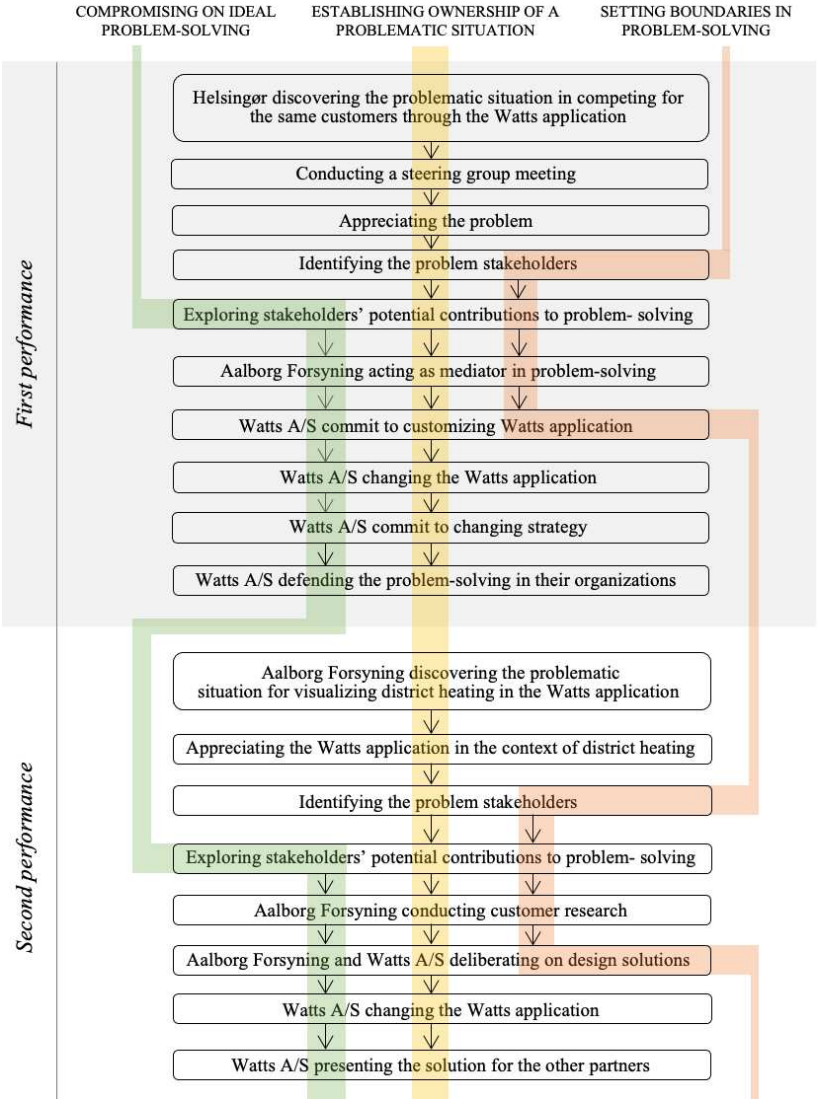

Figure 1. The three process threads in the two performances.

4.4 Establishing ownership of a problematic situation

We found that establishing ownership of a problematic situation is essential in collaboration between the organizations. Establishing ownership is a process that extends throughout the two performances of collaborative problem-solving and involves the problem owners' commitment to problem-solving, the partnership, and the consumer. Therefore, this process is more about taking *responsibility* in a problematic situation and is less about taking *control* of the problem-solving process.

4.4.1 First performance

In the first narrative performance, the process of establishing the ownership of the problematic situation begins with Helsingør discovering that Watts A/S promotes electricity on the Watts application. In discovering the problematic situation Helsingør Forsyning became an owner of the problem – committing themselves to find a solution within the partnership. Watts A/S established ownership of the problematic situation by conducting a steering group meeting inviting all the partners to appreciate it, thus showing that they take this issue seriously and, in solving this problem to avoid similar problematic situations in the future. The purpose of a steering group meeting was to recognize relevant stakeholders and appreciate the problem situation. In appreciating the problem situation, the partners saw the potential consequence, e.g., losing a Helsingør as a key partner. This dilemma made the collaboration difficult – essential resources such as time and money were used on this problem, thus taking resources away from accomplishing the shared goal of digitally transforming the energy sector toward sustainable development. Thus, the problematic situation extended beyond a disagreement between two partners – it affected the whole partnership. Therefore, Aalborg Forsyning chose to take ownership of the problem situation and enter the problem-solving, committing to solve the problem and further the shared goal of the partnership.

Solving the commercialization problem was not solely about accommodating the demands of a partner; it also became about how can Watts maneuver in this – **Project Manager, Aalborg Forsyning**

The problem owners – Helsingør, Watts A/S, and Aalborg Forsyning – were identified as the problem stakeholders. Each problem stakeholder explored how they potentially can contribute to problem-solving, thus, living up to their ownership of the problematic situation. Aalborg Forsyning lived up to their ownership of the problem by acting as a mediator in problem-solving. Aalborg Forsyning elevated the discussion above the disagreement between Helsingør and Watts A/S, reminding them of what they agree on – the shared goal to digitally transform the energy sector towards sustainability.

I think (CEO at Watts) called me a gatekeeper at one point or another. ... When someone starts going in a direction that is not okay, then I actually tend to say – Well yeah, but how was this partnership established? – **Project Manager, Aalborg Forsyning**

Watts A/S lived up to their ownership of the problem by customizing the Watts application so that Helsingør customers did not receive the promotions on electricity from Watts A/S, which Watts A/S implemented in the Watts application. Furthermore, Watts A/S and their board of directors committed to changing their strategy to avoid future conflicts of interest.

4.4.2 Second performance

In the second performance, Aalborg Forsyning discovered that the icon, which visualizes district heating in the Watts application, needed to be redesigned to communicate district heating more clearly to the consumers. In discovering this problematic situation Aalborg Forsyning took ownership of it, committing to accommodating consumer needs in collaboration with Watts A/S. Watts A/S established ownership of the problematic situation by committing to enter the problem-solving process together with Aalborg Forsyning. Here, Watts A/S took ownership of the problematic situation by appreciating the Watts application in the context of district heating. At the same time, Aalborg Forsyning took ownership of the problematic situation by conducting consumer research to understand consumer perception of district heating. These actions go beyond what both partners expected from each other; thus, they reinforced the established ownership of the problematic situation by exercising their commitment to problem-solving.

They [Aalborg Forsyning] *go in and are active players and bring real value to the table concerning the app's development. They also do this when we discuss how the User Interface – should be designed*
- Pod Owner, Watts A/S

After the problem stakeholders had explored and exercised their contributions, Aalborg Forsyning and Watts A/S began to collaboratively deliberate on the design solutions. In the process of deliberating, Aalborg Forsyning and Watts A/S met as equal problem owners. Both partners contributed with their ideas, concerns, and arguments and listened to each other until all problem owners were satisfied with the final visualization of district heating.

It is okay for everyone to say what one thinks. But it is a question of whether you want to keep trying again and again and again till we hit the right thing, so everyone thinks it is cool – **Project Manager, Aalborg Forsyning**

When Watts A/S and Aalborg Forsyning completed the deliberation process by agreeing on the solution, Watts A/S changed the Watts application, thus finalizing the problem-solving process. Later, Watts A/S presented the solution for the other partners, showing continued commitment to the solution.

4.5 Compromising on ideal problem-solving

Compromising on the ideal problem-solving is the second process identified in the organizations' collaborative problem-solving. Being part of a partnership, the problem owners compromise on the ideal problem-solving to deliver shared value (now or in the future) and not solely to themselves. In the two performances, compromising on ideal problem-solving is about involving and accommodating other partners in the decision-making.

4.5.1 First performance

The process of compromising on ideal problem-solving begins with exploring problem owners' potential contributions to the problem-solving process. First, the problem owners – Helsingør Forsyning, Watts A/S, and Aalborg Forsyning – had to consider whether they were ready to compromise. Helsingør Forsyning was not willing to compromise. Instead, Helsingør Forsyning viewed the problematic situation as a decisive moment – to remove the promotion from the shared platform or leave the partnering. This ultimatum made collaboration between Helsingør Forsyning and Watts A/S difficult – both parties had obligations to their organizations, which maintained them in the problematic situation.

It would be super annoying if Helsingør went away, but we can not completely change our strategy just because they were a good partner from the start. It's tough, but this is how it is. – **Pod Owner, Watts A/S**

Due to this stalemate in problem-solving, Aalborg Forsyning entered the problem-solving process as a mediator to negotiate a compromise on the ideal problem-solving by presenting an outside perspective on the problem situation. Trying to negotiate a compromise in this problem-solving was not a naïve endeavor. Aalborg Forsyning was aware of the ultimatum presented by Helsingør Forsyning but chose to advocate for a solution that kept Helsingør Forsyning as a partner.

Either you can accept it [Watts selling electricity on the application] *or you can not, and it ended up with Watts not being allowed to promote the electricity product through the app* – **Project Manager, Aalborg Forsyning**

In the end, because Watts A/S chose to compromise, they committed to customizing the Watts application temporarily. Watts A/S removed the electricity promotions from the shared platform. This compromise was not only about accommodating a partner's ultimatum but also about avoiding ending up in a similar problematic situation with other potential partners, which resulted in Watts A/S committing to rethinking its commercialization strategy. In this problem-solving process, Watts A/S chose to compromise on the ideal problem-solving and committed to rethinking their commercialization strategy. Furthermore, the process of compromising on ideal problem-solving continued when Watts A/S defended the solution to their board of directors. Thus, compromising on ideal problem-solving is an ongoing process because the compromise manifests in the solution to the problematic situation.

4.5.2 Second performance

In the second performance, the process of compromising also began with exploring the problem owners' potential contributions to problem-solving. Aalborg Forsyning and Watts A/S had to define to what extent they were willing to compromise on resources, customer-centricity, and decision-making. In searching for a compromise, the decision-making was not equally distributed between Aalborg Forsyning and Watts A/S. Even though Aalborg Forsyning is the one who identified the problematic situation – Watts A/S makes the final decision on any potential changes in the Watts application. Aalborg Forsyning is aware of this imbalance; however, they still experienced a fair problem-solving process – they were able to express their opinions, and Watts A/S listened.

Because Watts pays, it should be up for the discussion how much they should listen to us. But I think that all of us were allowed to comment and were heard […]It was a good process – **Project Manager, Aalborg Forsyning**

Watts A/S, being a decision-maker, made room for deliberation, which entails providing and listening to arguments on the design solution; thus, searching for a mutual ground. Therefore, Watts A/S is compromised on their decision-making power by accommodating and involving Aalborg Forsyning as much as possible in problem-solving.

We listen to them. Of course, we do not do everything they say; after all, it is us who develop Watts. But we will go to great lengths to make sure they are happy. And it means listening to good arguments – **Pod Owner, Watts A/S**

Through the deliberation, Watts A/S and Aalborg Forsyning agreed on a visual design solution that all approved; thus, reaching a mutual compromise. Watts A/S committed themselves to the compromise by implementing the agreed design and presenting it to the other partners. Similar to the first narrative performance, in the second narrative performance, compromising on ideal problem-solving is an ongoing process, extending beyond the problem-solving process because the delivered solution is rooted in the compromise – the compromise endures.

4.6 Setting boundaries in problem-solving

Setting boundaries in problem-solving is the last process that we identified as fundamental in collaborative problem-solving between Aalborg Forsyning and Watts A/S. We found that boundaries between the partnering organizations are neither fixed nor continuously ambiguous. Instead, the boundaries emerge every time organizations perform a problem-solving process – shaping and reshaping depending on the problematic situation in the digital transformation towards sustainability.

4.6.1 First performance

In the first narrative performance, the boundaries between the organizations begin to shape when organizations identify the relevant problem stakeholders. In identifying problem stakeholders, the organizations draw the boundaries of inclusion (and exclusion), assessing who is "us" and who are "them" in this problem-solving. Aalborg Forsyning does not have a direct conflict of interest with Watts A/S. Despite that, Aalborg Forsyning saw this as a joint problem, thus, setting new boundaries in the problematic situation.

The whole issue here is whether Andel [parent company of Watts A/S] *should be able to use their platform to sell their electricity product, but it collides with Helsingør. This is an issue that we have run into* – **Project Manager, Aalborg Forsyning**

The boundary-setting process becomes apparent in the language. The Project Manager uses the pronoun "their" and the pronoun "we" when referring to the ownership of the problem. Boundaries become more defined when each stakeholder explores their potential contributions to problem-solving; this action determines boundaries based on the limitations of resources and abilities to solve this problem.

Helsingør Forsyning clarified their boundary at the beginning of the problem-solving process by stating their ultimatum – to withdraw the promotion of electricity in the Watts application or leave the partnership. Aalborg Forsyning saw the potential to become a mediator in problem-solving and, in this role oscillating between the boundary set by Watts A/S and Helsingør Forsyning. Taking on the part of mediator, Aalborg Forsyning sought to help solve the problematic situation quicker, working towards furthering the shared goal of digitally transforming the energy sector in Denmark toward sustainable development.

It is very much such a community thing, we want to move forward with this [digital transformation]*, and we do it together* – **Pod Owner, Watts A/S**

Having Aalborg Forsyning as a mediator, oscillating between the boundaries, enabled the partnership to solve this problematic situation and shape and reshape it. As a result, boundaries in problem-solving are transactional – becoming in relation to actors, problematic situations, and reciprocity.

4.6.2 Second performance

In the second narrative performance, the boundaries between the organizations also begin to take shape when organizations identify the relevant problem stakeholders. The stakeholders explored their potential contributions to problem-solving. In this problem-solving process, both Aalborg Forsyning and Watts A/S entered each other's respective areas of expertise, thus blurring the boundaries between the two organizations. In this problem-solving process, both organizations went the extra mile – Watts A/S appreciated Watts application in the context of district heating, and Aalborg Forsyning used its resources to conduct customer research. Because both organizations performed a high level of engagement in problem-solving, the two organizations were able to deliberate on design solutions. In deliberation, the boundaries became increasingly more dynamic. Deliberating has shaped and reshaped the boundaries based on the presented arguments, design solutions, and differentiating views on the consumers' needs.

We talked, and the funny thing was that on both sides, there were divided views. So it was not because it was one side against the other side, not at all. It was very much based on what we thought the user needed. We all represented users – **Project Manager, Aalborg Forsyning**

In this performance, the boundaries were not set between organizations; they were set between arguments, opinions, and views. This type of boundary setting can be observed within a single organization or a single team. However, having the shared goal of digitally transforming the energy sector in Denmark and user-centricity as a mutual value, Watts A/S and Aalborg Forsyning took joint ownership of the problematic situation.

With Aalborg, we experience that we do it [problem-solving] *together, so it is our problem that we must solve in the best way possible. And that as soon as that problem becomes "ours" instead of "yours" and "mine," the solution will also be better* – **CEO, Watts A/S**

The CEO of Watts A/S uses the pronouns' our,' 'we,' 'you,' 'ours,' 'yours,' and 'mine' in a dynamic way (e.g., referring to a single organization, the partnership), unwillingly indicating that organizational boundaries become blurred and are shaped and reshaped through problem-solving.

5 Discussion

With our case study of digital transformation towards the sustainable development of district heating in Denmark, we explain how Aalborg Forsyning and Watts A/S collaborate in their problem-solving to address our research question: *How do organizations collaborate in a digital transformation towards sustainability?* In answering our research question, we identified two performances of their problem-solving process (cf. section 4.1 and 4.2). Across these performances, we found three processes that unfold how the organizations successfully collaborate by 1) *Establishing ownership of problematic situations* (cf. section 4.4) which regards the problem stakeholders' commitment to problem-solving, 2) *Compromising on ideal problem-solving* (cf. section 4.5) by involving and accommodating other

relevant partners in decision-making, and 3) *Setting boundaries in problem-solving* (cf. section 4.6) by ongoingly shaping and reshaping boundaries of the problematic situation. These processes are pervasive in the collaborative problem-solving between the two companies, seamlessly emanating and adapting to the problematic situations in the digital transformation.

Our focus on problem-solving performances has revealed not only what is being transformed (problem) but also how transformation occurs (solution) and why (shared values for sustainable development). Thus, we suggest that problem-solving should be a key concern for IS researchers to understand such inter-organizational collaboration (digital business ecosystem) in the digital transformation (Brusoni and Prencipe, 2013). Digital business ecosystems are fast-paced and turbulent, resulting in non-linearity and equifinality in the collaborative process (Hanelt *et al.*, 2021). This turbulence is a result of many "unknown unknowns" that organizations in a digital business ecosystem cannot predict (e.g., unexpected problematic situations); as such, these ecosystems are not expected ever to reach a kind of equilibrium (El Sawy and Pereira, 2013). However, even if equilibrium is never achieved in a collaboration process, using the theory of process multiplicity, it is possible to identify the underlying paths and patterns that are pervasive in this uncertainty. We illustrate this pervasiveness with the three process threads in Table 3 (c.f. section 4.3). Thus, we propose that process multiplicity theory can enrich IS research on digital transformation in the complex setting of sustainable development.

The three identified process threads are helpful for the practitioners who encounter unexpected problems in their digital transformation towards sustainability. While solving the unexpected problems, the practitioners and their collaborators should be aware of who establishes the problematic situation, whether there is a mutual willingness to compromise, and how the boundaries are set in the problem-solving process. We do not advocate planning and negotiating these processes before encountering unexpected problems; the two identified performances are illustrative examples of how these processes take shape and reshape, adapting to the problematic situation. However, our findings indicate that having a shared, unifying goal is useful in problem-solving by elevating the discussions and reminding the collaborators of what they agree on – namely, the unifying goal that guides the collaboration.

This case study has limitations. The first limitation is our focus on the collaborative problem-solving process. This excludes other types of collaborative processes such as information sharing or value creation (Berman and Marshall, 2014). Examining different types of collaboration in the digital transformation towards sustainability might reveal other underlying processes that seamlessly emerge and adapt to the situation. Another limitation of our work is regarding the small scale and scope of our inquiry. We examined two organizations in the context of district heating in Denmark and how they collaborate to solve problems. Therefore, it would be interesting to explore whether our findings are scalable and transferable to other contexts.

6 Conclusion

This paper reports how organizations collaborate in the digital transformation towards sustainability based on a case study of Denmark's district heating. Using the theory of Process Multiplicity, we analyze how two organizations can collaborate in a digital transformation towards sustainability. Our analysis of two distinct performances of collaborative problem-solving reveal three processes for how these organizations successfully collaborate by 1) establishing ownership of problematic situations, 2) compromising on ideal problem-solving, and 3) setting boundaries in problem-solving. With this analysis, we show that the Process Multiplicity theory can be useful in IS research to unveil the underlying processes of digital transformation towards sustainable development. We also show that problem-solving processes should be a concern for researchers of digital transformation in revealing what is being transformed (problem), how transformation occurs, and why.

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[P4] FOUR PROCESS VIEWS ON PROBLEM-SOLVING

[P4] **Ananjeva, A., Persson, J. S. & Nielsen, P. A., (2023) Digital Transformation towards Sustainability: Four views on problem-solving in the literature. Submitted to:** ***Fourteenth Scandinavian Conference on Information Systems (SCIS2023)***

Abstract:

Digital transformation holds vast potential to contribute to sustainable development by continuously addressing new or ongoing problems on organizational and societal levels. Therefore, to accommodate this ongoing problem-solving, we must understand and distinguish between different views on the role of digital technology in mitigating the climate change problem. We conducted a developmental literature review of the research fields dedicated to digitalization and sustainability. We identified the inherent views on problem-solving in 32 articles through our analysis. We synthesized four views on digital transformation towards sustainability: Optimization, Eco-feedback, Reflection, and Participation. Our findings present a synthesis of the four prevailing stances towards problem-solving and underlying assumptions in extant research on digital transformation towards sustainability. We discuss how our findings can support IS researchers' reflection on their underlying sustainability assumptions and how this can potentially guide stakeholders in co-creating environmentally sustainable futures.

DIGITAL TRANSFORMATION TOWARDS SUSTAINABILITY: FOUR VIEWS ON PROBLEM-SOLVING IN THE LITERATURE

Research paper

Abstract

Digital transformation holds vast potential to contribute to sustainable development by continuously addressing new or ongoing problems on organizational and societal levels. Therefore, to accommodate this ongoing problem-solving, we must understand and distinguish between different views on the role of digital technology in mitigating the climate change problem. We conducted a developmental literature review of the research fields dedicated to digitalization and sustainability. We identified the inherent views on problem-solving in 32 articles through our analysis. We synthesized four views on digital transformation towards sustainability: Optimization, Eco-feedback, Reflection, and Participation. Our findings present a synthesis of the four prevailing stances towards problem-solving and underlying assumptions in extant research on digital transformation towards sustainability. We discuss how our findings can support IS researchers' reflection on their underlying sustainability assumptions and how this can potentially guide stakeholders in co-creating environmentally sustainable futures.

Keywords: Digital transformation, Environmental sustainability, Process Views, Problem-solving.

1 Introduction

Climate change is one of the most significant challenges of our time. For instance, in 2022, disastrous flooding in Pakistan transformed fields of green into putrid lakes, laying waste to once fertile land and leaving the people of Pakistan without housing, food, clean water, and electricity (UNICEF, 2022). At the same time, Europe suffered one of the worst droughts in over 500 years, leading to heavy agricultural losses and contributing to the global food crisis (Masters, 2022). These devastating events are examples of the consequences of human-induced climate change (IPCC, 2022). Climate change is widespread and intensifying, which is why we are in dire need of solving this problem. One of the potential solutions to environmental degradation is digital technology (Seidel, Recker, vom Brocke, 2013). Thus, Information Systems (IS) research holds vast potential to contribute to sustainable development (Malhotra, Melville, Watson, 2013). The IS community has extensive knowledge of leveraging the transformative power of IS (Gholami *et al.*, 2016). The IS research has been concerned with information technology (IT)-enabled organizational transformation for decades, seeking to understand "how interactions between organizational contexts and IT systems impact transformation" (Wessel *et al.*, 2020, p. 104). In recent years, a new form of digitally enabled organizational change has occupied academics and practitioners, namely, digital transformation. Digital transformation can (re)define our core values (Wessel *et al.*, 2020) to positively mitigate the climate change problem by changing sustainability practices (Ågerfalk, Axelsson, Bergquist, 2022) on organizational and societal levels. The digital transformation towards sustainability (von Kutzschenbach and Daub, 2021; Ananjeva, Persson, Nielsen, 2022) emphasizes technology as a means towards solving the pressing challenges of our time (Gholami *et al.*, 2016) and not as an end. However, the literature on digital transformation towards sustainability is dispersed and characterized by different views on the role of digital technologies in sustainable development. For example, digital transformation can be viewed as a process of achieving

full automatization where the end goal is to reduce human intervention to achieve eco-efficiency (Chen, Boudreau, Watson, 2008, p. 190). On the other hand, others might view people as the engines behind the change (Biørn-Hansen and Håkansson, 2018) and not simply as contributors to an unsustainable way of living. From this point of view, digital technology's role is to increase people's engagement in environmental sustainability (Seidel *et al.*, 2018). This diversity indicates that there is no one path to guide researchers and practitioners in co-creating sustainable development - "there are no right or wrong answers, only answers that are better or worse from different points of view" (Introne *et al.*, 2013, p. 45). The lack of a clear path to follow emphasizes the wickedness of the climate change problem and the complexity of the digital transformation process. Thus, to manage this complexity, we adopt the view of sustainability as a process of continuously addressing new or ongoing problems (Tainter, 2011, p. 33). The different views on the role of digital technologies in sustainable development are rarely explicitly stated in the literature – these are underlying assumptions that guide problem-solving (Nielsen, 2020). Unless these underlying assumptions are checked (Schein, 1999), it is arduous to determine whether or not IS researchers should move in new directions. Thus, in this developmental literature review (Templier and Pare, 2015), we seek to disentangle these different views in order to uncover some underlying assumptions on digital transformation towards sustainability. Against this backdrop, we present our research question:

What do we know about the different views on problem-solving in the digital transformation towards sustainability?

To answer our question, we bring together the literature from two research communities: green information systems (Green IS) and sustainable human-computer interaction (Sustainable HCI). We analyzed this literature by identifying the problem, the proposed solution, and the consequent transformation in 36 articles. Through our analysis, we synthesized four views on digital transformation towards sustainability: Optimization, Eco-feedback, Reflection, and Participation. The different views offer alternative explanations of the problems and the solutions hereto. These alternative explanations present an overview of the prevailing stances on the role of digital technologies in sustainable development, thus, uncovering the underlying assumptions on sustainability in IS research. We hope this overview will contribute to IS researchers' reflecting on their underlying assumptions on sustainability. This reflection can potentially guide the engaged scholarship (Ågerfalk, Axelsson, Bergquist, 2022, p. 1) and aid in collaborative problem-solving between multiple stakeholders (Ananjeva, Persson, Nielsen, 2022).

2 Background

IS can potentially mitigate the climate change problem by lessening the environmental effects of human behavior(Watson, Boudreau, Chen, 2010). For over a decade, IS research has engaged in conceptualizing, analyzing, and designing such sustainable IS solutions (Gholami *et al.*, 2016); this research is particularly manifest in Green IS, which has become an accomplished field with the potential and responsibility to enable sustainable solutions (Brocke *et al.*, 2013). Much of the research conducted in Green IS is applied, design-oriented, and focuses on facilitating sustainable transformation in organizations (Seidel, Recker, vom Brocke, 2013; Recker, 2016). For instance, Seidel *et al.* (2018) conducted a Design Science Research (DSR) study that examines "how IS can support essential sensemaking practices in environmental sustainability transformations" (p. 1) In this study, Seidel *et al.* (2018) described digital technology's material properties to afford sensemaking activities in an organization. These design principles can be applied to design and develop solutions that influence an individual's behavior, i.e., by challenging what is socially acceptable in an organization. Furthermore, digital technology can enable decision-making and build a capacity to act sustainably (Corbett, 2013; Corbett and Mellouli, 2017). These studies are excellent examples of Green IS research; however, for the IS research to live up to its full potential in mitigating climate change, we must look beyond design-oriented research towards impactfulness (Gholami *et al.*, 2016). Thus, the true potential of IS research is realized when it makes an impact. The impact can be achieved when IS researchers actively engage in problem-solving activities in collaboration with the practitioners (Malhotra, Melville, Wat-

son, 2013). Our expertise can help to inform the climate change discourse and assist in designing and developing Green IS, thus, going beyond description and prediction (Ågerfalk, Axelsson, Bergquist, 2022). Therefore, it is purposeful to understand problem-solving already embedded in Green IS research.

3 Method

In our literature review, we adhere to the guidelines for *a developmental literature review* (Templier and Pare, 2015). The developmental literature review allows researchers to gather findings that focus on thematically dissimilar concepts, methods, and findings. Furthermore, in a developmental review, the focus is on central or pivotal studies. Finally, the product of a development literature review can be a conceptual framework and inspire new ideas (Templier and Pare, 2015). In our literature review, we had the following six-step procedure (see Figure 1).

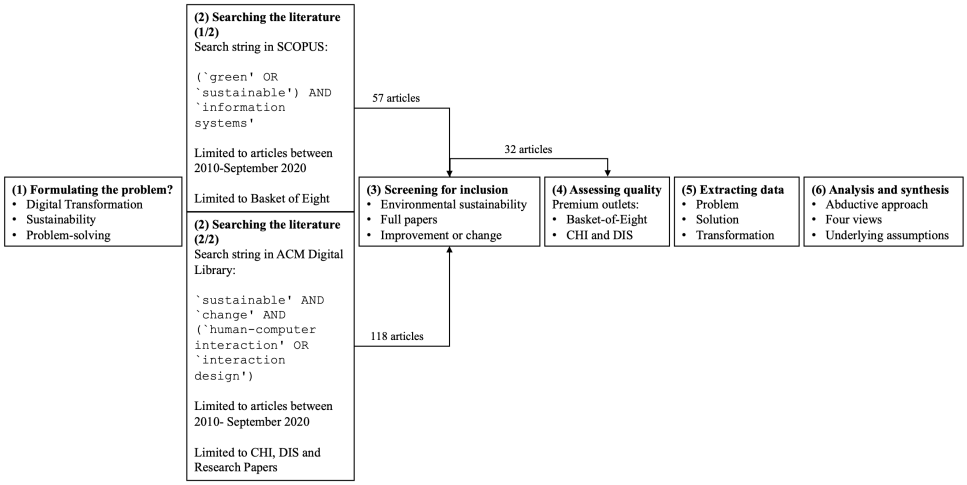

Figure 1. Literature review activities, adapted from (Templier and Pare, 2015)

(1) Formulating the problem: The literature on digital transformation towards sustainability is characterized by different views on the role of digital technologies in sustainable development. However, the different views on the role of digital technologies are rarely explicitly stated in the literature but are often implicit assumptions that guide problem-solving research. Therefore, the starting point of this literature review is the research question: *What do we know about the different views on problem-solving in the digital transformation towards sustainability?* This research question emphasizes our interest in *digital transformation*, *sustainability*, and *problem-solving*.

(2) Searching the literature: We have deliberately searched the literature related to *digital transformation* and *sustainability*. We excluded *problem-solving* because, as stated previously, problem-solving is rarely explicitly stated. To answer our research question, we brought together the literature from two research communities: green information systems (Green IS) and sustainable human-computer interaction (Sustainable HCI). Sustainable HCI literature was included in this review due to its explicit focus on the end-users. The knowledge of how to integrate end-users in sustainable development is very limited in the Green IS literature despite the end-users potential to drive sustainable development (Graf-Drasch *et al.*, 2022). For the IS literature, we have limited our search to the Basket-of-Eight journals (*European Journal of Information Systems, Information Systems Journal, Information Systems Research, Journal of AIS, Journal of Information Technology, Journal of MIS, Jour-*

nal of Strategic Information Systems, and MIS Quarterly) as a set of primary research outlets. In the human-computer interaction literature, we have limited our search to two top conferences – the ACM conferences on Human Factors in Computing Systems (*CHI*) and Designing Interactive Systems (*DIS*). Both conferences are considered prestigious outlets within the field of human-computer interaction. We were selective with the literature outlets because we did not seek to summarize all the existing knowledge regarding problem-solving in the digital transformation towards sustainability. Instead, we aim to uncover some of the underlying assumptions on sustainability in digital transformation literature – we problematize (Alvesson and Sandberg, 2020). The search terms in the two sets of literature were different due to differences in terminology in IS and HCI:

IS: `(`green' OR `sustainable') AND `information systems'`

HCI: `` `sustainable' AND `change' AND (`human-computer interaction' OR `interaction design') ``

The literature search was limited to the literature between 2010 and September 2020; the total search resulted in 175 articles (57 IS articles and 118 HCI articles).

Different views	References	Examples of data extraction
Optimization	(Watson *et al.*, 2011; Bengtsson and Ågerfalk, 2011; Benitez-Amado and Walczuch, 2012; Cooper and Molla, 2017; Wunderlich, Veit, Sarker, 2019; Wu and Devendorf, 2020; Zeiss *et al.*, 2021)	**Problem:** The current 'take-make-waste' economic model **Solution:** Optimizing the life cycle of the physical and digital artifacts **Transformation:** Supporting the circular economy (Zeiss *et al.*, 2021)
Eco-feedback	(Jönsson, Broms, Katzeff, 2010; Froehlich, Findlater, Landay, 2010; Watson *et al.*, 2011; Bengtsson and Ågerfalk, 2011; Strengers, 2011; Benitez-Amado and Walczuch, 2012; Thieme *et al.*, 2012; Corbett, 2013; Cooper and Molla, 2017; Wunderlich, Veit, Sarker, 2019; Wu and Devendorf, 2020; Zeiss *et al.*, 2021)	**Problem:** People lack information on, and interest in, their waste management in private households. **Solution:** Sharing information on unsustainable behavior with other people through digital technology. **Transformation:** Self-educating through information and improved waste management. (Thieme *et al.*, 2012)
Reflection	(Normark and Tholander, 2014; Entwistle *et al.*, 2015; Hasselqvist, Hasselgren, Bogdan, 2016; Raptis *et al.*, 2017; Jensen *et al.*, 2018a; Jensen *et al.*, 2018b; Biggs and Desjardins, 2020)	**Problem:** Washing practices are not disrupted enough. **Solution:** Design and deployment of a provocative probe. **Transformation:** Reflecting on the established washing practices. (Raptis *et al.*, 2017)
Participation	(Kim and Paulos, 2011; Normark and Tholander, 2014; Lessel, Altmeyer, Krüger, 2015; Hasselqvist, Bogdan, Kis, 2016; Biørn-Hansen and Håkansson, 2018; Heitlinger, Bryan-Kinns, Comber, 2019)	**Problem:** Integration of Green IS in organizations. **Solution:** Green IS promotion through a persuasive Green IS champion. **Transformation:** Green IS becoming a part of the organizational sustainability process. (Hedman and Henningsson, 2016)

Table 1. The four identified views, related references, and examples of analysis

(3) Screening for inclusion: We screened these articles for inclusion with the criteria that an article must refer to *environmental* sustainability, it must be a full paper, and it must report a *change* or an *improvement* due to our focus on the transformative power of digital technology. The screening process identified several articles that did not report an actual change but rather a wish. This process left us with 32 articles in total. The limitation of our literature search is related to our search criteria and the screening activities. Firstly, digital transformation is a term that is usually applied in IS research and is rarely used in the Sustainable HCI literature. Consequently, we found a synonym for digital transformation, which we defined as "Change," a possible source of error that could have eliminated relevant literature. Secondly, the included literature had to report *impact, change,* or *improvement*. This screening activity excluded much of the design-oriented literature.

(4) Assessing quality: This step implies a formal assessment of the studies' quality to refine the ones to include (Templier and Pare, 2015). However, due to our deliberate focus on premium outlets such as Basket-of-Eight, CHI, and DIS, we trusted that the quality assessment was conducted in each outlet's peer review process.

(5) Extracting data: We extracted the relevant data by identifying the problem, the solution, and the transformation (change/improvement) in each article (see Table 1). We asked each article the following questions: i) What is the core problem to be solved? ii) What is the solution to the core problem? iii) What has been transformed?

(6) Analyzing and synthesizing data: After identifying our data – the problems, the solutions, and the transformations – we applied abductive reasoning (Brinkmann, 2014) to identify distinct views on problem-solving. Through analysis, we synthesized four overarching views on the digital transformation towards sustainability: Optimization, Eco-feedback, Reflection, and Participation. Each view has its perspective on the problem, the solution, and the underlying assumption on sustainability.

4 Findings

We identified four different views on problem-solving in the digital transformation towards sustainability literature: Optimization, Eco-feedback, Reflection, and Participation (see Table 2). Each view is also subcategorized to further nuance the role of the digital technology in sustainable development. The four views have distinct perspectives on the problem, and the solution, which helped us identify the underlying assumptions on sustainability.

4.1 Optimization

The first identified view is Optimization. In this view, digital technology makes *resources, services, and infrastructures work efficiently and effectively towards sustainability goals*. The Optimization regards efficiency and effectiveness at all levels. In this view, using fewer resources to complete a task is seen as competitively and economically beneficial, e.g., optimizing resource-excessive services (Bengtsson and Ågerfalk, 2011). In addition, this process view entails optimizing: (i) the life cycle of the physical and the digital artifacts, (ii) organizational processes through support systems, and (iii) the digital infrastructures toward sustainable living.

Optimizing the life cycle of the physical and the digital artifacts: Some might perceive the Optimization process as efficiency-based; however, it also promotes a circular economy, which aims to minimize the input of technology and close material loops (Zeiss *et al.*, 2021). For example, Zeiss *et al.* (2021) problematize the take-make-waste economy in research and propose a solution to mobilize IS scholars towards a circular economic model. To create digital solutions for a circular economic model, researchers and designers need to understand software and hardware to create reconfigurable artifacts ready for re-purpose or repair, thus facilitating the disassembly and reassembly of artifacts innovatively and efficiently (Wu and Devendorf, 2020). This type of innovation is predominant in experimental research and lacks much information systems research (Watson *et al.*, 2011). This type of Optimization requires researchers and designers to get involved and gain an in-depth understanding of stake-

holders, their routines, and digital capabilities (Bengtsson and Ågerfalk, 2011). In a study of support systems for transport logistics and decision-making focusing on sustainability reporting and analysis, it was found that a support system could reduce CO^2 emissions by 80% in a year (Bengtsson and Ågerfalk, 2011).

However, the success of support systems depends on organizations' digital capabilities (Benitez-Amado and Walczuch, 2012). Digital capabilities positively affect implementing proactive environmental strategies that bring business benefits. The absorptive capacity also plays an essential role in the Optimization process (Cooper and Molla, 2017). Prior exposure and experience with sustainable digital technology in an organization increases knowledge acquisition, assimilation, and utilization of sustainable digital technology. Sustainable digital technology leads to a more effective infrastructure and practices (Cooper and Molla, 2017). Researchers and practitioners should explore digital technologies' ability to support and understand how technology can promote extended use of technology in practice.

Optimizing the infrastructure towards sustainable living: The Optimization process concerns digital technologies' ability to realize organizational and governmental sustainability goals through transforming physical and digital infrastructures (Bengtsson and Ågerfalk, 2011; Cooper and Molla, 2017). However, the lack of adoption of these technologies can undermine investment in sustainable technology (Wunderlich, Veit, Sarker, 2019). Therefore, to increase the intention to adopt, digital technology must provide meaningful extrinsic motivations for sustainability (Wunderlich, Veit, Sarker, 2019).

4.2 Eco-feedback

We define `Eco-feedback' as *promoting behavioral change through consumer data towards sustainability goals*. Research advocating the Eco-feedback view examines how digital technology can promote pro-environmental behavior in individuals or groups through information (Froehlich *et al.*, 2012). The Eco-feedback is built on the rational-choice theory. Rational-choice theory proposes that people will act per the information available to them and consume in a manner that "provides them with the most personal gain at the least personal cost" (Strengers, 2011, p. 2136). The Eco-feedback encompasses two concerns: (i) providing information to change the perception of the consumption by individuals, households, and organizations to support, motivate and provide perceived control, and (ii) providing information to change perceptions of energy to increase energy literacy.

Providing information to change the perception of consumption: The Eco-feedback view often manifests in eco-feedback systems, e.g., carbon management systems. The purpose of an eco-feedback system is to provide information and awareness about consumption habits (Froehlich, Findlater, Landay, 2010), which can be mediated in many different ways. On a household level, displaying disaggregated consumption data can motivate conservation behavior (Froehlich *et al.*, 2012). Eco-feedback systems are also helpful on an organizational level since individuals' behavior affects organizational environmental performance (Corbett, 2013). For example, an individual-level carbon management system can help engage ecologically responsible behavior in organizational employees, leading to positive changes in attitudes and behavior (Corbett, 2013). Thus, providing information on consumption is valuable for households and organizations. Eco-feedback systems aim to inform the consumer, contextualize consumption, and promote self-monitoring and self-reflective behavior (Thieme *et al.*, 2012). However, self-reflection is non-trivial and can be hard to initiate through design. In this case, a socially persuasive system can playfully engage thoughtful behavior in consumers and increase their perceived behavioral control (Thieme *et al.*, 2012). Thus, the perception of consumption can be changed through social pressure. For example, it was found that sharing information about unsustainable behavior with other people can evoke evasive feelings of guilt (Thieme *et al.*, 2012). However, guilt did not discourage the users but instead motivated them to use the system and improve their behavior (Thieme *et al.*, 2012). Thus, from this view, digital technology can enforce sustainable behavior and change consumers' perceptions through social pressure.

Providing information to change the perception of energy: The Eco-feedback also concerns changing the perceptions of energy to increase energy literacy. The idea is to minimize the energy literacy gap (Schwartz *et al.*, 2013) - also called the environmental literacy gap (Froehlich, Findlater, Landay, 2010). Multiple studies, e.g., (Strengers, 2011; Schwartz *et al.*, 2013), indicate that the problem is consumers have difficulty understanding and acting upon the data. On a household level, it was found that consumers learn about energy by following their consumption data, which increases energy literacy on an individual level over time (Schwartz *et al.*, 2013). Another problem the Eco-feedback view addresses are the intangibility of electrical consumption in a workplace (Jönsson, Broms, Katzeff, 2010). For example, Jönsson, Brom, and Karzeff (2010) studied how design can reduce electricity consumption and affect employee behavior. The identified solution was that tangible statistics could increase the employees' awareness of electricity consumption (Jönsson, Broms, Katzeff, 2010). Tangible statistics were built into a set of three oversized torches that presented real-time energy data of a factory. Through ambient light, the eco-feedback became tangible and understandable. The simplicity of design enabled the employees to draw their conclusions from the presented data and increase their understanding of the factory's energy consumption (Jönsson, Broms, Katzeff, 2010). However, this type of eco-feedback system is experimental and rarely applied in practice.

4.3 Reflection

We define the 'Reflection' as *challenging the status quo through design towards deliberate practices*. The core assumption of the Reflection view is that people are dependent individuals in a more extensive and complex set of social and cultural practices (Strengers, 2011). In this view, digitalization at a societal level ought to change social practices, not individual behaviors, and should not persuade but instead initiate reflection as a prerequisite for social change (DiSalvo, Sengers, Brynjarsdóttir, 2010). By viewing people as rational and autonomous, researchers fail to recognize that human consumption "is shaped by infrastructures, technologies, and institutions" (Strengers, 2011, p. 2136). Thus, solely focusing on individuals and neglecting the socio-technical context (Preist, Schien, Blevis, 2016). The Reflection view can be categorized in two ways: (i) reflecting on the established practices through provocation or limitation, and (ii) reflecting on the intangible through speculation and tangible artifacts.

Reflecting on the established: The Reflection view advocates an in-depth understanding of everyday practices (e.g., cooking and bathing) by challenging the structures that shape them (Entwistle *et al.*, 2015; Raptis *et al.*, 2017). Studies that encourage this view have been exploring how to release humans from the boundaries of the established structural constraints; however, the problem is that everyday practices are not disrupted enough (Raptis *et al.*, 2017). Practices are hard to change due to their seeming banality. One of the reasons practices are hard to change is digital infrastructures that maintain consumers' unsustainable practices. Prevailing practices are characterized by instant service, high quality, and ubiquitous computing; thus, they are perceived as unsustainable (Preist, Schien, Blevis, 2016). Accordingly, researchers ought to recognize the limits of digital growth and adhere to "computing with limits" (Preist, Schien, Blevis, 2016, p. 8).

One solution is the creation of provocative prototypes – provotypes - which can make the users reflect on their consumption practices and increase their awareness of environmental sustainability (Clear *et al.*, 2014; Jensen *et al.*, 2018a). Furthermore, the reflection can be achieved through *scripting* - a descriptive social norm (feature) embedded in digital technology (Pierce, Schiano, Paulos, 2010). The claim is that "scripting can be used as a conceptual tool for researchers and designers to help define what constitutes 'normal' behavior" (Jensen *et al.*, 2018a, p. 1388). However, the interventions, e.g., provotype or scripting, seem to be effective only when installed and do not sustain sustainable practices (Jensen *et al.*, 2018a).

Reflecting on the intangible: The Reflection view serves another purpose of making the intangible phenomena tangible, e.g., climate change. For example, the reflective process can be mediated through an artifact designed for embodied speculation (Biggs and Desjardins, 2020). A speculative artifact can

give a bodily experience of the intangible, e.g., changes in sea level in the future, to cyclists, thus making climate change more tangible to the cyclists (Biggs and Desjardins, 2020). In this perspective, the role of digital technology is not to impose disruptive ambiguity but instead challenge the status quo, or the intangibility, of climate change itself (Biggs and Desjardins, 2020). In addition, a speculative artifact opened opportunities for the users to speculate from their own "history of practice" (Biggs and Desjardins, 2020, p. 8). Thus, practitioners can use speculative artifacts to mediate empathy for the unfamiliar or the strange.

4.4 Participation

The antecedence of the Participation view is that people are the engines behind the change (Biørn-Hansen and Håkansson, 2018) and not simply a contributor to an unsustainable way of life. We define the Participation as *achieving change through engaging people*. In this view, engagement in the sustainability movement influences the actions required to achieve change. The Participation has two categories: (i) sustainable development *through* participation, a bottom-up perspective, and (ii) sustainable development *by* participation, a top-down perspective. We find the difference in whether participation involves people in co-designing activities (*through*) or people are the means towards sustainability (*by*).

Engaging people through participation: Organizations can lose the users' perspective and limit users' experiences with sustainable technologies in the race towards effectiveness. A proposed solution regards involving citizens in designing through co-designing activities, thus democratizing digital solutions (Heitlinger, Bryan-Kinns, Comber, 2019). Furthermore, organizational IT resources can enable organizations to develop sustainability capabilities that convey sustainable values to relevant stakeholders (Dao, Langella, Carbo, 2011). Such a resource can be a *sustainability champion* - a person who fights for sustainable values - who can help disseminate sustainable values among the employees (Hedman and Henningsson, 2016).

In this perspective, Green IS initiatives are perceived as successful if they lead to positive feedback, transform values, and increase the persuasiveness of the sustainability champion (Hedman and Henningsson, 2016). Furthermore, a successful sustainable Green IS initiative must scale to achieve the scope and scale required in digital transformation. Based on an examination of the practical experiences with scaling-up sustainability initiatives, it was found that the infrastucturing process and IT-supported collaborative practices help scale-up sustainability initiatives (Biørn-Hansen and Håkansson, 2018).

Engaging people by participation: Digital solutions can facilitate people actively participating in sustainability initiatives by invoking attachment towards a product (Kim and Paulos, 2011). However, it is also essential to provide an actionable context for sustainable initiatives (Seidel, Recker, vom Brocke, 2013; Hasselqvist, Bogdan, Kis, 2016) beyond the feeling of attachment toward a product. Collective action can be achieved by integrating the notion of *sensemaking* - construction of meaning to comprehend and act accordingly - with the idea of *affordances* - material properties of a digital solution that channels specific behavior (Seidel *et al.*, 2018). Information overload should be avoided in facilitating actionable context, and the "reciprocal interaction of seeking information, ascribing meaning and acting" (Seidel *et al.*, 2018, p. 222) should be furthered.

Thus, digital solutions should not passively feed information to the consumer. It should instead promote the interpretation of the information and give a space where experiences and assumptions can be challenged and shared (Seidel *et al.*, 2018), thus enabling decision-making and developing a capacity to act sustainably (Corbett, 2013; Corbett and Mellouli, 2017). Furthermore, when stakeholders share experiences, this allows for critical reflection (Lessel, Altmeyer, Krüger, 2015) and mutual inspiration, which strengthens the feeling of the community (Normark and Tholander, 2014). This knowledge-sharing process does not necessarily require a custom-made digital solution; it can also be conducted through existing social media (Tim *et al.*, 2018).

Aspects	Optimization view	Eco-feedback view	Reflection view	Participation view
Problem *What is the core problem to be solved?*	People are bound by unsustainable processes, infrastructures, and services.	People are unaware and, therefore, less sustainable.	People are bound by the status quo.	People are not activated or engaged.
Solution *What is the solution to the core problem?*	Continuous search for processes, infrastructures, and services to enhance.	Provide actionable consumption feedback to increase environmental literacy.	Create provocative and speculative designs to challenge the status quo.	Increase people's engagement in design activities and design to support sustainable user activities.
Assumption *What is the underlying assumption on sustainability?*	Sustainability pertains to efficiency and effectiveness.	Sustainability is actionable information.	Sustainability is a radical change in the state of mind.	Sustainability is increased human engagement.

Table 2. The problems, solutions, and assumptions on sustainability in the digital transformation towards sustainability

5 Discussion and Conclusion

This literature review sought to disentangle the different views on digital transformation towards sustainability in order to answer the research question: *What do we know about the different views on problem-solving in the digital transformation towards sustainability*? We have identified four views - Optimization, Eco-feedback, Reflection, and Participation - distinct in their understanding of the problem, solution, and underlying assumptions on sustainability. We do not argue whether some views are superior to others – they are all valid from their points of view. These different points of view offer alternative explanations on the role of digital technology, organizations, and the consumer in solving the wicked problem of climate change. Alternative explanations are welcomed and inevitable in this process because "there are no right or wrong answers, only answers that are better or worse from different points of view" (Introne *et al.*, 2013, p. 45). Thus, seeing the process of digital transformation towards sustainability through a single view might help IS researchers in disentailing this wicked problem – breaking it down into smaller and more manageable pieces.

However, applying a single view on the climate change problem can create an illusion of a single solution to a grand challenge, thus, alienating potentially valuable ideas that might contribute to the overall goal of sustainable development. Therefore, to guide this problem-solving process, the co-creators of sustainability need to be aware of these differences and reflect on possible paths (Pentland *et al.*, 2020a) to take in the digital transformation process. We see the digital transformation towards sustainability through the lens of process multiplicity as the duality of one and many (Pentland *et al.*, 2020b); many paths lead to the desired outcome. We argue that by acknowledging that there are multiple views on the problems and solutions, it is possible to expand the space of possible paths (Pentland *et al.*, 2020a) that could be taken in a digital transformation journey.

Furthermore, digital transformation towards sustainability calls for *engaged scholarship* (Van De Ven, 2007). Based on our findings, we further suggest that researchers need to be aware of the four distinct views (cf. Table 2) while engaging in the practice. The IS researchers can reflect on their own diverse (or even conflicting) perspectives on the problem, the solution, and the underlying assumptions on sustainability. This reflection can potentially guide the coveted engaged scholarship (Malhotra, Melville, Watson, 2013; Ågerfalk, Axelsson, Bergquist, 2022) and even help facilitate the co-creative ac-

tivities between multiple stakeholders. For example, through a longitudinal case study, Ananjeva, Persson, and Nielsen (2022) illustrate how an inter-organizational digital transformation journey can non-sequentially encompass different views on problem-solving. The practitioners successfully navigated different views in their inter-organization collaboration by i) reciprocating each other's perspectives on the problem and the solution, ii) responding to turbulence in the environement by encompassing multiplicity of views, and iii) by continuously reassessing the past from different perspectives to adjust for future action (Ananjeva, Persson, Nielsen, 2022). Thus, if the underlying assumptions remain unchecked, the IS researchers might not be able to determine when or how to move in new directions (Schein, 1999). We might not recognize the new paths and how to navigate this problem-solving journey with others.

For example, suppose the researchers in collaborative efforts towards sustainable development with the practitioners have an underlying assumption that sustainability is a radical change is the state of mind (Reflection view). In that case, they might want to develop provocative digital artifacts. If the practitioners, however, assume that sustainability pertains to efficiency and effectiveness (Optimization view), they would want to target their effort towards developing efficient services and infrastructures. The two views could potentially inform each other, contributing to the development of a multifaceted solution that solves more than one problem. However, if the two views are competing, this might lead to misunderstandings, inhibiting collaborative efforts. That being said, there is no way to establish a future free of conflict - the best we can do is to establish norms for recognizing and resolving disagreements (Hardimon, 1992). Our findings contribute to creating a potential framework (see Table 2) for recognizing disagreements on the problem, the solution, or the underlying assumption on sustainability.

Our literature review is not without limitations due to the predefined conditions in our search criteria and the screening activities. Firstly, digital transformation is a term that is applied in IS research and is rarely used in the Sustainable HCI literature. Consequently, we found a synonym for digital transformation, which we defined as "Change," which is a possible source of error that could have eliminated relevant literature. Secondly, the included literature had to report a change or improvement. This screening activity excluded much of the design-oriented literature that did not intend to or go as far as change or improvement. Design-oriented research is essential and should be on the agenda for IS research; "Green IS needs to be normative and develop design theory, design principles, and actual designs" (Ågerfalk, Axelsson, Bergquist, 2022, p. 4). However, our literature review did not seek to summarize all of the existing knowledge regarding digital transformation towards sustainability. Instead, we aimed to uncover some underlying sustainability assumptions in digital transformation literature (Alvesson and Sandberg, 2020).

Furthermore, the different views on digital transformation towards sustainability are merely 'snapshots' of problem-solving in IS research; thus, we call for future process studies. Process studies explain the change as a category of concepts concerning actions or a narrative describing how things develop and change (Van De Ven, 2007, p. 196). Thus, through process studies, it would be possible to gain an insight into how the four views on digital transformation towards sustainability develop and change *over time*. That being said, we do not claim to have identified *all* views on problem-solving in the digital transformation towards sustainability; there might be more. Including design-oriented literature could potentially reveal other views on problem-solving in the digital transformation towards sustainability.

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[P5] PROCESS VIEWS IN DISTRICT HEATING

[P5] **Ananjeva, A., Persson, J. S. & Nielsen, P. A., (2022) Digital Transformation towards Sustainability: A Case Study of Process Views in District Heating,** ***The 13th International Conference on Software Business (ICSOB'22)***

Abstract:

Digital transformation (DT) has the potential to change our society toward the United Nation's sustainable development goals. However, developing software for the DT towards sustainability is a complex process that may entail an emphasis on optimization, eco-feedback, reflection, and participation. This paper contributes to a better understanding of how organizations navigate this complexity of different process views with a case study of a DT in district heating. Based on ten interviews with a software development company, eight interviews with a district heating supplier, and 14 interviews with consumers, we analyze the process views on their DT. This analysis shows how organizations navigate the different process views in a DT journey when encountering and solving problems. We conclude the paper by providing propositions on what *navigating* DT implies. Furthermore, we discuss how these insights can help practitioners navigate different process views and how our findings nuance the understanding of the DT process.

Digital Transformation towards Sustainability: A Case Study of Process Views in District Heating

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Abstract. Digital transformation (DT) has the potential to change our society toward the United Nation's sustainable development goals. However, developing software for the DT towards sustainability is a complex process that may entail an emphasis on optimization, eco-feedback, reflection, and participation. This paper contributes to a better understanding of how organizations navigate this complexity of different process views with a case study of a DT in district heating. Based on ten interviews with a software development company, eight interviews with a district heating supplier, and 14 interviews with consumers, we analyze the process views on their DT. This analysis shows how organizations navigate the different process views in a DT journey when encountering and solving problems. We conclude the paper by providing propositions on what *navigating* DT implies. Furthermore, we discuss how these insights can help practitioners navigate different process views and how our findings nuance the understanding of the DT process.

Keywords: Digital Transformation, Process Views, Navigating, Sustainability

1 Introduction

Climate change is one of the greatest challenges of our time, and digital transformation (DT) has great potential to enable sustainable development [1, 2]. In the face of climate change, the scope of DT is expanding, including an increased focus on society and the individual and their role in sustainable development [3, p. 1]. In this process, digital technology can be seen as "a contributor and a potential solution to environmental degradation" [4, p. 1278]. That being said, the DT process towards sustainability is a tortuous journey with many proposed solutions, including optimizing the life cycle of the physical and digital artifacts [5], pro-active strategies [6], infrastructuring [7, 8], and increasing people's engagement in sustainability [9]. This diversity illustrates the wickedness of the climate change problem [10]. Wicked problems are "problems for which no single computational formulation of the problem is sufficient, for which different stakeholders do not even agree on what the problem really is" [11, p. 45]. We have identified four streams of literature with distinct process views on the DT towards

environmental sustainability: optimization, eco-feedback, reflection, and participation. These processes differ in their view on the problem, solution, and sustainability. Thus, there is no silver bullet and no clear path that helps organizations navigate sustainable development – the practitioners must manage problems and solutions that unfold in real-time. However, the literature falls short in describing *how* this dynamic process develops over time. Against this backdrop, we present our research question:

How do organizations navigate the different process views in the digital transformation towards sustainability?

To answer our research question, we conducted a longitudinal single-case study [12] of the DT of district heating [13] in a municipality in North Jutland, Denmark. In this case study, we followed the development of the Green Assistant - an application that provides hourly consumption data on heat, water, and electricity. This application is developed in a partnership between multiple organizations. In this article, we follow two organizations – Joules A/S (a software development company) and NortHeat (the heating domain expert) – and how they navigate the different process views in their DT journey. Furthermore, we interviewed district heating consumers in NortHeat's municipality to understand how the solutions made in the partnership influenced them.

With this case study, we build and illustrate a theory of how organizations can navigate the different process views in a DT journey. We use the distinction between the four identified process views – optimization, eco-feedback, reflection, and participation – to build a theory of multiple process views on DT towards sustainability. Furthermore, we provide propositions on what *navigating* DT implies. These insights can help practitioners navigate different process views on DT and nuance the understanding of the DT process. Lastly, we present limitations of our study and an agenda for future research.

2 Process views on DT towards Sustainability

In the relevant literature, we identified four process views that illustrate how the processes of DT towards sustainability can unfold: Optimization, Eco-feedback, Reflection, and Participation.

The optimization process view on DT towards sustainability promotes effectiveness and efficiency. Using fewer resources is seen as competitively and economically beneficial, e.g., optimizing resource-excessive services [14]. For example, in a study of support systems for transport logistics, focusing on sustainability reporting and analysis, it was found that a support system could reduce CO_2 emissions by 80% in a year [14]. From the optimization perspective, transforming the physical infrastructures through digital technology contributes to organizational and governmental sustainability goals [14–16]. However, these interventions require significant investments, and the lack of adoption of these technologies can undermine this investment in sustainable technology [16]. Thus, this process view is also concerned with how people can adopt these technologies and live up to the technology's potential to support sustainable consumption.

The eco-feedback process view on DT towards sustainability promotes behavioral change through consumer data. The Eco-feedback process is built on the assumption that people will act per the information available and consume in a manner that "provides them with the most personal gain at the least personal cost" [17, p. 2136]. From this process view, the purpose of digital technology is to provide meaningful information about consumer consumption [18]. Furthermore, it is argued that digital technology can help change consumers' perceptions of energy and increase energy literacy [19]. Consumers can learn about energy by following their consumption data over time [19]. However, it has also been shown that some consumers have difficulty understanding and acting upon the information [17]. Thus, it is essential to consider how this information should be visualized to become meaningful, thus leading to sustainable consumer behavior.

The reflection process view on DT towards sustainability promotes challenging the status quo through design towards deliberate practices. The reflection process view advocates that digitalization at a societal level ought to change social practices and initiate reflection as a prerequisite for social change [20]. The reflection process view advocates a thorough understanding of everyday practices (e.g., cleaning and cooking) to challenge the unsustainable structures that shape them [21, 22]. From this process view, the prevailing practices characterized by instant service, high quality, and ubiquity are unsustainable [23]. The proposed solution is to make the consumers reflect on their consumption practices and increase their awareness of environmental sustainability [24, 25]. Thus, the reflection process view is about learning, awareness, and deliberate practices.

The participation process view on DT towards sustainability promotes achieving change through increased people's engagement. Organizations can lose the users' process view and limit users' experiences with sustainable technologies in the race towards effectiveness. A proposed solution regards involving citizens in designing through co-designing activities, thus democratizing digital solutions [26] or introducing a *sustainability champion* - a person who fights for sustainable values - to disseminate sustainable values among the employees [27]. In this view, the role of digital solutions is not to feed information passively to the consumer but to give a space where experiences and assumptions can be challenged and shared [9]. Thus, enabling decision-making and developing a capacity to act sustainably [28, 29]. Furthermore, when stakeholders share experiences, this allows for critical reflection [30] and mutual inspiration, strengthening the community feeling [31]. In this process view, human engagement in sustainable development becomes the key to achieving sustainability. Therefore, digital technology assumes a supportive role in establishing shared values, practices, activities, and knowledge.

We have summarized and operationalized the four process views by identifying their different success criteria for developing software for DT towards sustainability (see Table 1). These different process views offer alternative explanations of the *problem*, the *solution,* and *sustainability*. The alternative explanations to the climate change

problem are inevitable because "there are no right or wrong answers, only answers that are better or worse from different points of view" [11, p. 45]. Thus, we theorize that DT towards sustainability is a single process [32, p. 121] that can unfold in a multiplicity of ways [33].

Table 1. The process views on the digital transformation towards sustainability

Process Views	The problem, the solution, and view on sustainability
Optimization	*The problem* is that people are bound by unsustainable processes, infrastructures, and services. *The solution* is a continuous search for processes, infrastructures, and services to enhance. *Sustainability* pertains to efficiency and effectiveness
Eco-feedback	*The problem* is that people are unaware and, therefore, less sustainable. *The solution* is to provide actionable consumption feedback to increase environmental literacy. *Sustainability* is actionable information.
Reflection	*The problem* is that people are bound by the status quo. *The solution* is to create provocative and speculative designs to challenge the status quo. *Sustainability* is a radical change in the state of mind.
Participation	*The problem* is that people are not activated or engaged. *The solution* is to increase people's engagement in design activities and design to support sustainable user activities. *Sustainability* is increased human engagement.

3 Method

To unfold the four process views on DT towards sustainability, we conducted a longitudinal single case study [12] of how NortHeat and Joules A/S navigate different process views on the DT of district heating. Our units of analysis were problem-solving actions, and to identify what actions constitute the different process views, we applied the success criteria for DT towards sustainability (see Table 1). One way of capturing a process is through narrative [34]. Therefore, in our inquiry into actions that constitute the DT of the district heating process, we conducted narrative interviewing [35] with several relevant stakeholders from both organizations over two years.

The relevant stakeholders were organizational employees who had a decisive role that impacted how both organizations navigated the different process views. Based on this criterion, we interviewed the CEO at Joules A/S, the R&D Section Manager from Joules A/S, the Head of Energy Supply, and the IT Project Manager from NortHeat (see Table 2). The interviews' purpose was to gather insight into how the two organizations

viewed and solved situated problems that guided this DT journey. This DT journey started in 2018 as a collaboration between NortHeat and Joules A/S to exploit data from the installed smart meters in the district heating area's 110.000 households.

Table 2. The number of interviews and the stakeholder description

Data collection	Stakeholders
Joules A/S 10 Semi-structured interviews (February 2020 – February 2022)	• 5 x Section Manager responsible for R&D • 3 x Section Manager responsible for partnering with Utility companies • 2 x CEO responsible for vision and mission for Joules A/S
NortHeat 8 Semi-structured interviews (September 2020 – February 2022)	• 5 x Project Manager responsible for Green Assistant roll-out • 2 x IT-Project Manager responsible for digital infrastructure • 1 x Head of Energy Supply er responsible for providing vision and mission for the DT of district heating.
Green Assistant users 14 Semi-structured interviews (April 2020 – November 2020)	• 2 x Finn, a Construction Engineer – uses the app monthly • 2 x Svend, a Municipal Worker – uses the app weekly • 2 x Anne, a Municipal Worker – uses the app daily • 2 x Erik, a Taxi Driver – uses the app monthly • 2 x Karen, a retired Secretary – uses the app monthly

NortHeat has been working towards producing renewable energy heat and sought to transform district heating digitally. Therefore, NortHeat partnered with Joules A/S – an electricity provider and an application developer. They did not buy or sell services or products from each other. Instead, they pooled their resources and capabilities into developing a consumer-oriented mobile application for tracking and predicting heat consumption. Joules A/S benefited from this collaboration regarding data access, a large user base, and expertise in district heating. NortHeat, on the other hand, benefited from access to skilled developers and an already working solution that had proven its worth for electricity consumption.

Nevertheless, both organizations shared an overall concern for sustainable energy consumption in their digitalization efforts. Yet, as shown by the subsequent unfolding of the four process views, they still entailed ambiguity when navigating the more specific concerns in practice. Furthermore, we have conducted two rounds of semi-structured interviews with seven citizens of NortHeat's municipality (see Table 2). We used insights from these interviews to illustrate how the consumers perceived the solutions made in the partnership. For all the interviews, we used interview guides and recorded them through Microsoft Teams or a recording device (the interview guides will be provided on request).

In our analysis of the interviews, we identified problem-solving actions conducted by various stakeholders that illustrate how organizations navigate the different process views on the DT towards sustainability through the following steps (adapted from [36]):

1) We listened to all recordings, transcribed them, and read the transcriptions to familiarize ourselves with the empirical data.
2) Critically identify quotes in the data and code these appropriately in relation to the four identified process views (see Table 1):
    i) We searched for problems, solutions, and views on sustainability in the empirical data.
    ii) We operationalized four process views by codifying their different success criteria for developing software for sustainability (e.g., the optimization process view had codes such as *service, infrastructure, process, efficiency,* and *effectiveness).*
    iii) We checked if the identified problems, solutions, and different views on sustainability work in relation to the identified four process views (e.g., if a quote referred to any kind of *efficiency* and *effectiveness,* we related it to optimization).
3) The chosen quotes were analyzed to illustrate how organizations navigated this DT journey:
    i) We searched for decisive action in the DT process that enabled the organizations to continue their journey (e.g., reciprocating each other's process views).
    ii) From these actions, we have abductively [37] elicited three propositions on what navigating DT towards sustainability entails.

4 Analysis

In the following sections, we unfold how NortHeat and Joules A/S navigate the four process views in their DT journey. In addition, we incorporated the consumers' experience with the Green Assistant to gain an understanding of how the actions made in the partnership influenced and were perceived by the consumers.

4.1 The optimization process view

The optimization process promotes effectiveness and efficiency; sustainability is viewed as using fewer resources to complete a task. This process view was pervasive in Green Assistant and NortHeat's actions and overall vision for their DT journey. One of the significant challenges was unreliable access to consumption data. NortHeat was ambitious to create a digital service that offers consumers *fast* and *frequent* consumption data; thus, they installed smart meters in 110.000 households. The old flow-based system did not support the new task of providing consumers with a frequent and detailed consumption overview. The new smart meters could provide each household's heating data hourly; thus, it was essential to ensure that data flow is constant and seamless to the consumer:

Our largest challenge, almost from day one, is the delay in the data. Sometimes it's two days, and it's funny because that's fast compared to what we are used to, but the consumer, for instance, is used to looking things up on Facebook and not having to wait days before it gets into the app. (Head of Energy Supply, NortHeat)

The Head of Energy Supply at NortHeat describes this optimization challenge as an issue of consumers' expectations towards what is *immediate* consumption. He believes that consumers' expectations are formed by using other digital technologies, not their current heating practices. Therefore, the organization sought to make a robust digital infrastructure without delay in data. As a result, the two organizations – Joules A/S and NortHeat – had a workshop in which they jointly solved this optimization problem:

We make linear smoothing of data and other calculations before sending data to Joules. Our role is to make sure that Joules receives quality data that fits with their neural network, which makes "the budget." (IT Project Manager, NortHeat)

After the workshop, the two organizations designed a solution that accommodated the needs of both organizations. When receiving smart meter data from the third-party data supplier, NortHeat processed the received data to accommodate the digital infrastructure at Joules A/S. Thus, NortHeat ensured the best possible consumer experience with the Green Assistant. This optimization issue is currently partially resolved. The delays in data are still occurring; however, these occurrences are less frequent and less perceivable by the consumers. Furthermore, as described by the R&D Section Manager, the goal of this DT journey is a complete automatization of energy flow in a household:

We have a saying at our parent organization – "We create energy to live life." This sound fluffy, but we want to help people so that it becomes easy to live their lives. We want to take care of everything else and try to make it as green as possible – complete automation of the energy flow in the home. (R&D Section Manager, Joules A/S)

The ambition to automate the energy flow in the home presents an insight into how Joules A/S perceives sustainability and the consumers' role in the sustainability movement. Sustainability is viewed as an automated and reduced energy flow in a household. Thus, from the optimization process view, the part of a consumer becomes passive – they should be able to live their lives while the optimized infrastructure supports their everyday practices. This view is shared by Finn, a construction engineer:

It would be way more convenient to buy something that could be more efficient, and then you wouldn't have to think about it again for some time. (Finn, Interview 1)

Finn prefers not to frequently interact with his energy system, which endorses Joules A/S's ambition to create a "complete automation of the energy flow in a home." During the optimization process, the two organizations navigated through consumers' expectations of digital services and the limitations of the digital infrastructure.

4.2 The eco-feedback process view

The eco-feedback process view on DT towards sustainability promotes behavioral change through consumer data; sustainability is viewed as actionable information enabling energy-conservation behavior. The eco-feedback process view is predominant when NortHeat and Joules A/S are working on solving a need to increase the consumers' energy literacy about heat and sustainability. One of the significant challenges from

this process view is communicating consumption in an understandable and actionable way. This challenge is particularly evident in how to communicate *sustainable* consumption. Initially, the consumption was provided through a budget. However, providing the monetary value of the consumption does not necessarily promote conservation behavior – the assumption is that if the energy is cheap, people will use it. A proposed solution was to communicate the CO_2 emissions of a household. However, this solution is limited by the consumers' (lack of) knowledge about the CO_2 emissions:

*CO_2 is difficult to understand. A hundred grams CO_2, how much is it? We see our task to explain consumption differently. We can tell you how green you are. But how do we define "green"? One way is to show a percentage in reduction. This is at least something we hear a lot about and something that could be more intuitive for consumers. (*R&D Section Manager, Joules A/S)

Joules A/S found that the CO_2 emissions are not *intuitive* for the consumers and are challenging to understand and act upon. This solution is not feasible from the eco-feedback process view, which emphasizes the *actionability* of the information. Therefore, Joules A/S, in collaboration with NortHeat, is currently working on solving this energy-literacy issue. In heating, one of the eco-feedback issues is teaching the consumers what good and sustainable heating consumption is. Joules A/S and NortHeat work iteratively on finding a design that provides enough information so that the consumer understands the nuances of heating consumption and can act on it:

First, we did some reasonably complex mock-ups and ran a demo for NortHeat. And we were told that "It may be too complex, they [consumers] cannot understand it," - so we took a few iterations where we cut it to simplify it. (CEO, Joules A/S)

As exemplified in the quote by the CEO of Joules A/S, providing enough information without increasing the complexity of the Green Assistant is a tricky balance to find. In navigating this issue, Joules A/S relies on NortHeat's understanding of the heating domain and its consumers. Both organizations are collaborating on designing a solution that balances the need for simplicity and detail. That being said, this issue does not only belong to the heating domain - balancing simple and detailed eco-feedback is an issue within all areas of energy and resources (water and electricity):

We swing a lot between different extremes when we design this app; it should be as simple as possible, but […] if we have any relevant information, we should not hide it. (Pod Owner, Joules A/S)

As described by the Pod Owner from Joules A/S, identifying the balance between simplicity and detail is an iterative process, which requires reflection from the designers and developers. The reflection regards identifying what is *relevant* information and how it could be presented without increasing the complexity. However, the interface of an application can also become too simple. For example, Svend became frustrated while using the Green Assistant because he could not get the information the way he was used to:

I don't understand why they've chosen to show consumption as money spent. Down on my meter, it's written in m^3 and temperature, but there's no simple way to show that

in Green Assistant unless you, of course, download the raw data, but then I might as well read [the meter] myself. (Svend, Interview 2)

Svend is a knowledgeable consumer who was already frequently interacting with his energy system. Svend argues that presenting the consumption as money spent did not necessarily represent *actual* consumption. His understanding of relevant information is firmly rooted in his previous experience with his heating system – going down to his cellar to read his meter, which provided the consumption information in m^3 and inflow temperature. Svend's assessment of the application illustrates how difficult it can be to balance the needs of consumers with varying levels of knowledge.

In the eco-feedback process, the two organizations navigated the delicate balance between the consumers' knowledge about sustainability and what is perceived as relevant information by the consumer.

4.3 The reflection process

The reflection process view on DT towards sustainability promotes challenging the status quo through design towards deliberate practices. In our case, *deliberate* practices imply a greater consciousness about energy production and consumption. The status quo to be disrupted is how consumers understand energy consumption and their role in energy production, consumption, and trading. The reflection process view is predominant when Joules A/S presents its vision for the future of electricity in Denmark:

The next thing we look at is energy communities; if a household has too much electricity, then it should be able to sell it to its neighbor. Why should we not be able to make use of surplus energy and sell it at better prices while alleviating the electricity grid? Something should be done about that, and we view it as our future mission. (R&D Section Manager, Joules A/S)

As described by the R&D Section Manager from Joules A/S, the ultimate goal of this DT journey is to disrupt the energy system. They view the disruption as democratizing energy trading and deliberate peer-to-peer trading, enabling a stronger energy community. Joules A/S views its role as a mediator promoting and supporting the energy community. However, NortHeat does not have the same ambition:

We do not have an exaggerated expectation that consumers will have to sit daily and trade energy. The energy flow must run automatically, but consumers must be involved somehow. (Supply Manager, NortHeat)

As described by the Supply Manager at NortHeat, they view the end goal of this DT journey as a full automatization and an increased involvement of the consumers. This difference in the end goal may be due to differences in the resources the organizations produce. For example, Joules A/S is a daughter company of a larger electricity concern in Denmark, and electricity is one of the resources consumers can produce themselves. NortHeat is, however, among other things, a heat provider. Unfortunately, heat is a resource that is difficult to make and trade peer-to-peer.

Furthermore, from the reflection process view, consumer involvement implies changes in practices towards more deliberate energy consumption through the Green Assistant. Anne is an illustrative example of how an application can change consumers' practices:

You bet it has worked […]! It's almost a game for us, you know, getting to the next level by using less than the day before […]. [When] it was a bit cold in the morning, I thought "no" to myself. Because I can read the heat consumption, I choose to put on one more sweater instead of turning up the heat. (Anne, Interview 1)

Anne explains that her heating practices were changed due to the Green Assistant, e.g., putting on a sweater instead of turning up the heat, thus, enabling a more deliberate energy conservation practice.

With this process view, we illustrate how two organizations can have different aspirations for the DT journey while collaborating. In the reflection process, the two organizations navigated by accepting different end-goals of the journey.

4.4 The participation process view

The participation process view on DT towards sustainability promotes achieving change through increasing people's engagement. This process view is predominant in how NortHeat and Green Assistant's A/S view the consumers' role in the sustainability movement. In the sustainable transition of district heating, consumer engagement is vital because energy use and energy production are mutually dependent – a utility company must supply energy that meets the consumers' demand. Therefore, they are not just passive stakeholders but critical actors that can further or hinder this sustainability transition:

The system is as strong as its' weakest link. […] Consumers must be a part of this transition, but that is a difficult task. For the past ten years […], we have looked into it and found that there's almost nothing as uninteresting for people as energy use in their houses. […] So, our task is to get consumers more engaged. (Supply Manager, NortHeat)

The Supply Manager sees the consumers as the *weakest link* in this sustainable transition. NortHeat's decade-long experience has shown that consumers are not interested in their heat consumption, and increasing engagement is not an easy task. Therefore, in distributing the Green Assistant, NortHeat is trying to increase the consumer's interest. Both NortHeat and Joules A/S see this task as one of the shared goals of this DT journey:

Our goal is to engage our customers and help them become more sustainable. But more importantly, to make it easy for them to do and be green. (R&D Section Manager, Joules A/S)

The R&D Section Manager at Joules A/S emphasizes the need to engage the consumers to act sustainably and "more importantly" make it *easy* to do and be sustainable. This emphasis on easiness demonstrates that Joules A/S does not view engagement as *activism*, which might imply radical and ongoing action for change. Instead, Joules A/S

views engagement as a long-term commitment to sustainable living by investing in automation (e.g., smart thermostats or smart power outlets). This view is based on the assumption that consumers, on average, are not willing to engage with their energy system often and deliberately. For example, Erik, a taxi driver, used the application to engage more with his heating system from a more informed position:

Yeah, it's nifty because I usually can see […]whether we're good or bad that day and if we need to improve. If it's red, I probably have to turn down the thermostats or something. Before, you didn't really have a clue. (Erik, Interview 1)

Another way Joules A/S and NortHeat have engaged the consumers in this DT journey is by viewing them as co-creators. For example, NortHeat has a focus group of consumers commenting on interface design in the Green Assistant. Furthermore, NortHeat and Joules A/S use customer support to gain consumer feedback on their experience with the application for future application iterations.

The participation process view presents a new insight into consumers' role in navigating this DT journey. The consumer is essential in this journey in two ways. Firstly, the consumer's engagement in DT is vital because energy use directly influences how energy is produced. Secondly, the consumers are value co-creators by helping identify new ways of improving the application.

5 Discussion

There is no clear path that helps organizations navigate sustainable development because "there are no right or wrong answers, only answers that are better or worse from different points of view" [11, p. 45]. Thus, a DT process towards sustainability can unfold in a multiplicity [33] of ways (see Table 1), which increases the process's complexity. We theorize that this process consists of at least four process views: optimization, eco-feedback, reflection, and participation. In illustrating our theory through a longitudinal case study, we found that the DT towards sustainability is a process that can non-sequentially encompass all four process views. In the relevant literature, process views can be perceived as mutually exclusive. For example, the eco-feedback process view is criticized for viewing people as rational and autonomous. The critique is that designers and software developers fail to recognize that human consumption "is shaped by infrastructures, technologies, and institutions" [17, p. 2136]. However, our process theory of four views on DT suggests that all four process views can be present in a DT process without being mutually exclusive – a single journey can have multiple paths toward the desired outcome. Based on our illustrative case study, we present three propositions on what the process of navigating a DT journey implies:

Involvement of multiple stakeholders that reciprocate each other's process views: In our case of DT towards sustainability, the organizations pooled their resources and capabilities into a solution meeting the needs of both organizations and the consumers. For example, NortHeat processed the received data to accommodate the digital infrastructure at Joules A/S. This finding supports previous research stating that the DT

process goes beyond the collaborative efforts of a single team, a single organization, or a single project process [38]. Developing software for DT requires involving customers in becoming value co-creators [39, 40] and establishing strategic partnerships with external organizations [41]. To successfully navigate a DT journey, the partnering organizations must collaboratively move towards a shared vision [42]. In the case we studied, this collaboration implied the different stakeholders reciprocated each other's process views. For instance, Joules A/S and NortHeat view consumer engagement as a long-term commitment to sustainable living by actively investing in automation and participation, which is also evident in their effort to increase the consumers' energy literacy about heat and sustainability through eco-feedback.

Responding to turbulence in the environment while encompassing multiple process views: In navigating the DT towards sustainability, the two organizations had to deal with turbulence in the environment. Turbulence is the condition of "unpredictability in the environment because of rapid changes in customer needs, emerging technologies, and competitive actions" [43, p. 444] — for example, the consumers' expectations towards what is *immediate* heating consumption. The two organizations recognized that consumers' expectations were formed by using other digital technologies, and their digital infrastructure needed further development to solve this problem. Thus, our case study corroborates the previous research that responding to turbulence or changes in the environment is a vital organizational capability in a DT process [44]. However, we add that successfully responding to the turbulence in the environment encompasses multiple process views. For example, while responding to the consumers' expectations, the organizations simultaneously (i) accommodated what consumers view as immediate eco-feedback, (ii) sought to increase (and accommodate) the consumers' energy literacy, (iii) supported (and challenged) consumers energy practices, and (iv) involve the consumers as co-creators or value. Thus, in terms of process multiplicity theory [33], responding to the turbulence in the environment can open the space of possible paths to follow, which helps in discovering paths not yet taken.

Reassessing the past process with different views to adjust the plan of action: We found that navigating DT is not a simple sequential process; it is an ongoing reassessment of past process views to adjust the course for the future. For instance, the Green Assistant provided consumption through monetary value, which did not further the overall goal of the two organizations to engage the consumers to act sustainably – navigating in the 'wrong' direction. The two organizations had to reassess the decisions made in the past to identify a new way of providing consumption information in a manner that promotes sustainable behavior. A single decision is not self-contained; it changes over time and has consequences for future work. Our third proposition thus corroborates the process multiplicity theory [33] that the past carries the potential for what can happen in the future [33, 45].

Our findings are helpful for practitioners in two ways. Firstly, organizations should be aware that there are multiple process views. This awareness can contribute to developing more multifaceted software that addresses more than one problem. Secondly, when

collaborating with other stakeholders on developing software for the DT, simply being aware of other processes' views is not enough. To successfully navigate the DT process, the organizations must i) reciprocate each other process views, ii) respond to the turbulence with a multiplicity of process views, and iii) reflectively reassess the past to improve and plan for the future.

Our process theory has limitations that invite future work. The first limitation is regarding the small scale and scope of our inquiry. For example, we examined two organizations in Denmark's district heating context and how they collaborate in navigating their DT journey. Therefore, exploring whether our findings are scalable and transferable to other DT journeys, e.g., waste sorting [46] or the transport sector [47] would be interesting. The second limitation is the focus on problems and solutions – there might be another way of differentiating the paths in the DT process. For example, a literature review [48] distinguishes the processes in DT by identifying the *advantages* and *disadvantages*. We, however, did not find any of the process views superior to the others.

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