Industrial Excess and the Reproduction of Power

Encountering the Work of Heating a Danish City with Facebook Data

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Publication date:
2023

Document Version
Publisher's PDF, also known as Version of record

PhD Thesis

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Industrial Excess and the Reproduction of Power: Encountering the Work of Heating a Danish City with Facebook Data

PhD Thesis
Submitted March 31, 2023

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Research funding by the Velux Foundations (PIs Vasilis Galis and Brit Ross Winthereik, project ID: 26584), the IT University of Copenhagen, and the Technical University of Denmark.

Cover photo: Odense energy plant (Fynsværket) owned and managed by the local utility Fjernvarme Fyn. Photo taken by the author in November 2020.

Abstract

This PhD thesis in Science and Technology Studies (STS) explores effects of the digital economy through ethnographic fieldwork in Odense, Denmark, on the emerging connections between energy and data storage. The thesis is overall drawn together in the study of how energy production is connected to the reproduction of the digital economy. It shows the need for detailed insights into how utility workers carry the heavy load of decarbonising energy and industrial energy consumption.

The three vectors of the connection are: 1) infrastructures of public heating and data storage; 2) the political constellation co-constituted with Facebook's entry into Odense; and 3) the epistemic meetings in the engineering practice.

The first article shows how the excess air emitted from the Facebook datacenter in Odense is in vernacular terms 'industrial excess'. The enrolment of the heating utility to datacenter exemplifies the different boundaries of production and consumption of late industrialism. These relations need reconceptualization to account for how the energy production of utilities and commodity production of industries are not equally industrial and therefore have different effects on escalating climate change.

The second article unfolds how Facebook managed to cement itself in the city of Odense. This analysis takes the approach that the platform is the most prominent 'layer' of the digital economy, where the platform is akin to the visible tip of the iceberg. Yet, it argues that the visible platform obscures the political relations of reciprocity between the technology company and politicians that exchange land, energy, and autonomy to receive (unfulfilled) promises of economic rewards for the welfare state.

The final article documents how public sector engineers connect large heat pumps to the excess air generated by the datacenter, while simultaneously contending with market pressures from small, individual, private heat pumps driven by climate policy. The engineers employ the law of energy conservation in thermodynamics to decarbonise energy but is interrupted with the economic competition as a law to market dynamics. In doing so, the engineers' insistence on the monopoly of public, non-profitable heating provides a lesson for dealing with the monopoly of tech companies.

The thesis concludes that the power to share energy between public and private actors is enabled by an existing infrastructure around district heating as well as ongoing utility work. Ethnographic utility studies as exemplified with the thesis helps us better understand how politics in the age of the digital economy are incremental and exposed to economic interruptions. Conceptualisations of the distinction between public and private actors have with the study shown to be inadequate for grasping the power at play in efforts to decarbonise energy and require to be reconceptualised in the realm of differences between shared and industrial infrastructures. The maintenance of critical infrastructure within planetary boundaries therefore hinges on the extension of the shared, non-profitable, local ownership and responsibility forms of district heating onto other infrastructures as well as practical intervention into the proportions of industrial production.

Resumé

Denne ph.d.-afhandling i Science and Technology Studies (STS) udfolder gennem etnografisk feltarbejde i Odense den digitale økonomis effekt på nye forbindelser mellem energi og data-opbevaring. Afhandlingen bidrager med studiet af, hvordan energiproduktion er forbundet til reproduktionen af den digitale økonomi. De analytiske resultater viser et behov for yderligere indsigt i forbindelsen mellem, hvordan energiarbejde på offentlig, kritisk infrastruktur trækker det tunge omstillings-læs, mens industriers energiforbrug til vareproduktion vokser.

Forbindelsen uddybes gennem tre indgange: 1) infrastrukturer – offentligt ejet fjernvarme og dataopbevaring; 2) den politiske konstellation ved Facebooks ankomst til Odense; og 3) epistemiske sammenstød i ingeniørernes praksis.

Den første artikel viser, hvordan overskuddet af luft fra serverne i Facebooks datacenter for fjernvarme-ingeniørerne er 'industrielt overskud'. Opkoblingen af fjernvarme til datacenter eksplicerer de forskellige grænser mellem produktion og forbrug i sen-industrialismes tidsalder. Det er for at anskueliggøre, hvordan energiproduktion foretaget af offentlige energiselskaber og vareproduktion foretaget af industrier ikke er lige dele industrielle (som ofte fremstillet), hvorefter deres effekt på og ansvar for klimaforandringerne må skelnes yderligere imellem.

Den anden artikel uddyber, hvordan Facebook formåede at cementere sig i Odense. Her vises, hvordan interaktionerne på digitale platforme ofte belyses som altoverskyggende i den digitale økonomi, mens de kun er toppen af det politiske isbjerg. Et andet lag i den digitale økonomi er det gensidighedsforhold mellem teknologivirksomhederne og politikere, der udveksler byggegrunde, energi og autonomi for at modtage (uopfyldte) løfter om bidrag til at vedligeholde velfærdsstatens økonomiske grundlag.

Den tredje artikel dokumenterer, hvordan energiingeniører forbinder store varmepumper til den overskydende luft fra datacenteret. Samtidig skal de skal forholde sig til markedspresset fra små, individuelle, private varmepumper, der fremskyndes ved klimaloven. I artiklen vises, hvordan økonomisk konkurrence kolliderer med ingeniørernes termodynamiske praksis. Værdien af monopolet ved offentlig, ikke-profitabel og billig fjernvarme, som ingeniørerne viser, anvendes som læringsrig kontrast til den politiske håndtering af techindustriernes monopol-position.

Afhandlingen konkluderer, at styrken ved at dele energi mellem offentlige og private aktører er muliggjort gennem eksisterende fjernvarmeinfrastruktur. Etnografiske studier af offentligt energiarbejde, som afhandlingen ekspliciterer, hjælper med at forstå, hvordan politik i den digitale økonomis tidsalder er udsat for økonomiske forstyrrelser. Det konceptuelle skel mellem offentlige og private aktører er utilstrækkelig i omstillings-arbejdet og må omformuleres til at belyse forskellene mellem henholdsvis delte og industrielle infrastrukturer. Vedligeholdelsen af kritisk infrastruktur indenfor planetære grænser afhænger derfor af overførslen af de succesfulde politiske resultater ved fjernvarme – lokalt, non-profitabelt, delt ejerskab og ansvar – på andre infrastrukturer, samt praktisk indgreb i proportionerne af industriel produktion.

List of articles

This dissertation contains three submitted original research articles and a short reflective piece from an edited collection that together make up chapters of the thesis.

Salling, Caroline Anna, and James Maguire. Servers, currents, and utility workers: When industrial excess became a tool, not a feature, never a bug.
(in review, *Engaging Science, Technology, and Society*)

Salling, Caroline Anna, and Brit Ross Winthereik. Datacenter politics and welfare politics: Layers of reciprocity in the digital gift economy.
(in review, *Science as Culture*)

Salling, Caroline Anna. The social life of scientific laws: Colliding market dynamics and thermodynamics in engineers' decarbonization work.
(submitted, *Social Studies of Science*)

Salling, Caroline Anna. In press. Speculation. In *Reclaiming Technology: A Poetic Scientific Vocabulary*, edited by James Maguire and Brit Ross Winthereik. Copenhagen: Ctrl+Alt+Delete Books.

Acknowledgments

Upon opening this file or print, please feel free to read non-linearly and to jump to any parts that might spark your interest. As this document is a thesis about infrastructural connections, some of those connected parts might be interesting to some and absolutely boring to others. Yet I have made it my mission, since I was first inspired by utility work, to show why it is both interesting, important, and more spectacular than what it might seem to the majority of people. Let it be known that I have attempted to provide enough context and literature in each article so that they each provide an academic contribution and hopefully interesting story on their own.

To even get to this place where someone (you) can read the contents of the thesis, has required work that has only been possible due to the many supportive relations I have been pushed into, been withheld within and (most of all) critically needed. As I am writing these acknowledgments weeks away from finalising the thesis (certainly a form of procrastination from writing that first draft of the conclusion), I am reminded of how I hope I have been able to give a fraction back of what I have received from the lot of you that I have depended on and come to know during these last 3 years.

Before starting my PhD research, I knew that if I was to embark on such an adventure, I could only do it in a place with colleagues that I hoped some of which would become friends, and with people and settled infrastructures that were made to constantly challenge the forcefield of lonely, independent person-organised, hierarchical academia. Simy Kaur Gahoonia and I, having initiated and worked towards the same PhD deadline, have at times told colleagues that we were writing a co-thesis, double tracked in The Body Multiple (Mol 2002) style or 1 page switch between our different topics. Half-jokingly, certainly longing for such a collective possibility, to me it was an affirmation that someone this smart would want to even just imagine writing together.

Technologies in Practice (at the IT University of Copenhagen) was the research group I wanted to become embedded within when I came home to Denmark from my master's studies in Edinburgh. My supportive friends Josefine Ranfelt and Bertil Ipsen introduced me to Rachel Douglas-Jones, whom I was enthralled to be helped by in order to find a formalised place - starting with an internship in ETHOS Lab. James Maguire, that as co-supervisor opened his own research field and interests to me these past years as well as shared much useful advice, and gave me an opportunity to work within *the* environment I had hoped for. Brit Ross Winthereik encouraged me to formulate a research project on 'district heating' (that I had shortly before researched in the context pf Shetland), introduced me to a wealth of literatures, infrastructures, norms (and how to navigate them) and people within her own professional world, and later became a formal supervisor and personal mentor that I could look up to, was there when needed, and always felt trusted and supported by. Brit is also the reason I came to the Technical University of Denmark in Lyngby where I spent the last 6 months of my PhD in an exciting and new research group of Responsible Innovation and Design. Thanks to all of you in my new division for letting me tag along with Brit, for all the practical work it took to transfer my project, and for carving a space for my research

and in which I cannot wait to get to know you all and your research better. I can already brag about having made connections that I treasure, for example Amanda Mogensen and Corinna Nathalie Voll that are the kind of colleagues everyone should have, and Maja Horst and Monamie Bhadra Haines for giving me wonderful feedback shortly before my thesis deadline.

The other PhD students whom I have organised formal and informal events and bonds with during the research are Andy Lautrup, Barbara Patricia Nino Carreras, Cæcilie Sloth Laursen, Katja Sara Pape de Neergaard, Lara Tatjana Reime, whom I am extremely happy to have formed friendly collective support bonds with. Many of us also became infrastructural lifelines for each other while initiating our PhD studies during the first covid-19 lockdown. Colleagues that also helped me in the process of carrying out this endeavour are Baki Cakici, Bastian Jørgensen, Cancan Wang, Christopher Gad, Irina Papazu, Jessamy Perriam, Katrine Meldgaard-Kjær, Marisa Cohn, Michael Hockenhull, Nanna Bonde Thylstrup, Pedro Ferreira, Sunniva Sandbukt. Thank you for making me feel like more than a forced junior colleague. Casper Bruun Jensen gave me – what I would not expect him to call – 'critical' feedback on one of my first article drafts. Steffen Dalsgaard, Irina Papazu and Julia Velkova – as my PhD midway committee – delivered both the necessary news of being well on the way and the need for stepping up my writing game. Julia was so much more than a host during my research stay at TEMA T in Linköping: a friendly informal supervisor, also as I was introduced to new PhD colleagues like Camilo Castillo, Alvaro Alarcon, Hanne Cox, and Hilda Wenander.

The research I have embarked on this time was not only possible but also an enjoyment as I was welcomed and integrated so well during my fieldwork in Odense, particularly by my friendly interlocutors whom I will not name here as they are pseudonymised in the thesis. When you encouraged me to further my engineering deep-dive into energy, district heating and thermodynamics, so I could work with you guys, I certainly felt accepted into your world.

Friends that insist that they are friends even when adult life comes upon one: the inspiring group of people I first came to know when we made the 'tech ants reading group' during our bachelor studies (including Daniel Bach and Frederik Philipsen) and discussed books such as those by Tsing, Barad, Deleuze and Guattari and Hardt and Negri over discount beers, the herd of fierce women from gymnasie times, and Mi (that was my first academic partner when we wrote about parliament elections and interviewed politicians in 8th grade). It all started back then! A heartfelt thanks to my three life companions and flatmates (two more feline than the one): Dale, Bonnibel, and Marceline, for both being interested in my work (the less feline one certainly a tad more) and distracting me sufficiently to make this research not simply possible but giving me good enough life conditions (fed, watered, rested, entertained, loved) to also make it super fun and exciting. To Christoffer, Benny, and Neel for always indulging me in both the curiosity and stubbornness that has led me here – this is also a result of your care and encouragement for everyday untamed adventures, generative discussions, and mostly living life beyond, not through, intellectualism!

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Chapter One: Introduction

[O]ne set of beliefs would see the energy problem as one of developing new supplies to meet the expanding energy needs; another might see the problem as one of reducing energy appetites, and yet another belief system might perceive the energy problem as a choice between hazardous, centralized systems and decentralized systems that had less hazardous potential. The differing ideologies are associated not only with different expert advice, but also with differing organizations of expert knowledge.
- Laura Nader (1980, p. 1)

While many events have contributed to reorganizing energy systems since Nader wrote about relations between beliefs and energy problems, many of the conditions giving rise to the problems remain the same. In 2022, the price of energy and therefore also the price of everyday commodities skyrocketed exponentially in many places at a speed not seen since the 1970s. This time around it was the limited flow of gas as a consequence of the Russian invasion of Ukraine that impacted many people's energetic everyday lives. Calls to reduce energy consumption, including tips and recipes for how to do so, quickly became a popular topic of interest in news articles and parliaments, and even among those who, due to forms of economic privilege, had never experienced the need to think about personal energy relations before. However, as I argue, there is critical potential in studying energy beyond how it is consumed.

The study of energy is a topic of still growing interest in the social sciences, probably stemming from concerns with energy's role in governance, and climatic and environmental impact. The first such anthropological studies, interpreted the invention of energy infrastructures and thermodynamic theory as one of the core milestones in the progress to contemporary human life and cultures (White 1943). As Boyer (2015) and Loloum, Abram, and Ortar (2021) describe, with the progression of this research trajectory, the 1970s and 1980s witnessed a second wave with increasing ethnographic sensibilities that moved away from building universal theory. Nader's (1980) seminal work centred energy as a concurrent social and environmental issue due to resource extraction and everyday lived impacts on, for example, miners, landscapes, and bodies in the form of pollution (Smith and High 2017; Rolston 2013).

Contemporary studies of energy are fuelled both by public concerns with climate change and energy transitions, and the emergence of Science and Technology Studies (STS) as a research arena in which themes such as ontological politics, socio-technical systems, and knowledge production are stabilized matters of concern. In the following paragraphs I review the literature in STS and related fields on the issue of how to decarbonize energy, exploring the conclusions presented by various scholars to position my study on processes of *energy production*.

1.1 The issue of how to decarbonize energy

Fuels hold political power, both in shaping the societal structure of contemporary democracies as a form of economic exchange (Menchaca 2016; Mitchell 2011) and as the material base for major companies once merely in the oil production business but now with a focus on a wealth of different (potential) fuels (Pinkus 2016). Fuels have both societal and elemental histories as they all depend on the flow of earth cycles and how they intervene in situated events (Vemuri and Barney 2022). They are often regarded as 'resources' because they are resourceful in sustaining the systems that depend on burning material compounds with energetic potential (Levidow and Raman 2020; Maguire 2020; Malm 2016; Richardson and Weszkalnys 2014), often circulating as alternatives to money, capital, and finance (Özden-Schilling 2021; Doganova and Karnøe 2015; Rohracher 2009).

Coal and oil are among the cheapest fuels because companies and governments have continuously extended and invested in the systems needed to produce them, while local inhabitants have both acquired salaries from extraction work and been displaced from their homes by them (Curley 2019; Wilson, Carlson, and Szeman 2017). The role of fuels, particularly the continuous distribution and burning of fossil fuels, despite decreasing in some places, is not only societal but also human. 'Petrosubjectivity' (Diamanti and Szeman 2020), referring to the petrographic study of mineral and textural compounds of rock formations as well as to human experiences, describes how all lives are in different ways impacted by the production and use of fossil fuels. While the extraction of fuels often extends old struggles related to colonial violence and sovereignty (Weszkalnys 2015) – for example, on indigenous lands in the US (Estes and

Dhillon 2019) – in other places, such as Norway, fuels are worked on politically to take shape as a public good (Lautrup 2022; Monteiro 2022). However, while Norway has experimented with distributing the wealth from oil, goods from fuel extraction rarely come to benefit anyone other than those already in economic elite positions (Lennon 2020; Cumming 2018).

New technologies are increasingly employed in both linking and extending energy systems in order to extract fuels from wind, seas, rivers, and the rays of the sun. This has required the construction of whole new distribution systems and market models across national, regional, and local borders, which often produces thorny issues connected with economic and political organization as well as expertise (Chen, Tilt, and Zhan 2022; Iychettira 2021; Sareen 2020; Howe 2019; Boyer 2019; Silvast 2017; Sovacool 2016; Hawkey et al. 2015; Silvast, Hänninen, and Hyysalo 2013; Summerton 1992; Hughes 1983). Who should own and maintain these systems and distribute the produced energy that has come to be just as important as the distribution of fuels? 'The grid' is an energy sector term that references the overall, increasingly convergent systems that are only interlinked at all due to communication technologies, transformers, pumps, cables, and so on (Boyer 2015). Conceptualizing this complexity as a technological grid is a way of holding together the multiple centres and peripheries of control and dependence (Abram 2022).

Newly adopted technologies often remake people's everyday life with energy. New meters require new forms of knowledge (Wade, Hitchings, and Shipworth 2016), and gendered affections for emerging energy tech matter for how and whether they are adopted (de Wilde 2020); on the other hand, public and local resistance leading to controversy and impasse can be generated by a range of factors. These include 'not in my backyard' logics (Kirkegaard et al. 2021; Papazu 2017a; Aitken 2009); the centralized enforcement by the international corporations who build large-scale energy systems (Haines, Moore, and Adornetteo 2023; Haines 2019); and technology construction that is enabled by colonial land (dis)possession (Estes and Dhillon 2019). Funding, planning, building, and using energy technologies is not only dependent on fossil fuels; it also requires work, dialogue, and the overcoming of new organizational challenges (Maguire, Watts, and Winthereik 2021; Watts 2019; Papazu 2018). Yet even

then, technology construction projects to harness more sustainable sources of energy, such as wind power, rarely fully replace fossil fuels but, rather, displace them into other places in 'the grid' (Günel 2022; Bell, Daggett, and Labuski 2020). Meanwhile, grids as technological systems are in many places treated as rather mundane and outdated, and generally under-maintained because innovation is expected to happen at the individual technology level (Günel 2021).

Production, as a certain professional and infrastructural mode, has received much more interest in yet another material component of this body of literature. Social studies of energy mainly focus on the production of energy data rather than the production of energy for data production. Since the birth of the engineering disciplines, energy waste from machines and buildings has been handled through attention to 'energy efficiency' (Daggett 2019). Efficiency measures at the global policy level have been treated as one of the main drivers for decarbonization, nourishing hopes for new machines that are less hungry for fuels (Shove 2018). Efficiency metrics are equally intrinsic to engineering practices and the standardization of both data and energy infrastructures, particularly as it becomes more and more difficult to tell the latter two apart. Most energy infrastructures are highly dependent on live and long-term data analysis of used water, electricity, heat, and IT, while much energy work depends on new meters, models, and processing (Monteiro 2022). This concept of 'energy efficiency' has by definition only become more and more narrow since its instrumentalization in legal standards such as those introduced by EU policy (Dunlop 2022).

Energy efficiency is now measurable in close to real-time and comparable through the increased production of all kinds of new energy data; yet these promises of efficiency are rarely constructed with any limits on what and who can be measured computationally (Mattern 2021). Transitions from fossil fuels to renewable energy are often imagined as problems to be solved by coordinating flows of energy by real-time measurement (Müller and Sareen 2022). The more data that is produced to reflect production and consumption, the more energy is planned, modelled, governed, and studied with the goal of decarbonizing energy by making it more 'flexible' (Pallesen and Jacobsen 2021). Yet building the 'the smart city' as a form of governed urban climate transition by collecting more data and cross combining more infrastructures turns out

to require whole other forms of organization than merely planning and policy, particularly as humans intervene in unexpected ways, and technologies never fully work as promised during development (Parks 2020). The issue ahead, then, is tuning in on how everyday lives with datafied energy connect with major technology and policy trends that travel with considerable power between parliaments, homes, utilities, companies, public institutions, and landscapes in which fuel extraction still takes place on a large scale (Goldstein and Nost 2022; Abram et al. 2022).

Yet another issue troubles this agenda: not only is the decarbonization of energy an emergent focus, some energy consumers also require increasing shares of the produced energy for their operations. The companies that depend on hyperscale data production and processing demand secure electricity and cooling for fuelling increasingly hungry servers and super computers, and this industry is only expected to grow exponentially (Hogan, Edwards, and Cooper 2022; Ensmenger and Slayton 2017; Hogan 2015; Carruth 2014). Thus, cool climates well-marketized for wind turbine construction and stable electricity currents become both political and ecological home environments for the production of energy for hyperscale data production (Ortar et al. 2022; Lally, Kay, and Thatcher 2022; Libertson, Velkova, and Palm 2021; Bresnihan and Brodie 2021; Maguire and Winthereik 2021). Meanwhile, the energy issue of data production and storage for the digital economy is complicated by projects between local and national governing institutions and tech companies to utilize the warm air from datacenter servers to distribute through local urban and suburban heating networks (Velkova 2021; Velkova 2016); thus, the energy used in data production is more than a simple, one-way extraction. Nonetheless, tech companies' consumption still relies just as much on fossil fuels as energy consumption by anyone else.

One of the reasons fossil fuels are so hard to phase out is the enormous levels of energy consumption required by contemporary locked-in commodities and large-scale processes such as mobility, logistics, and manufacturing. Moreover, while energy consumption is culturally dependent, it also intervenes in cultural life; when electricity arrives in new terrains, everyday practices are remade and challenged (Winther 2008). But consumption is also an issue that lives at many other scales than in everyday household and community practices (Strengers 2013), although it is usually treated as

an economically framed 'demand problem' that can be solved through usage reduction usually involving habit change at the level of individuals (Dubois et al. 2019; Shove and Trentmann 2018; Pallesen and Jenle 2018; Ryhaug, Skjølsvold, and Heidenreich 2018; Strengers 2013; Gram-Hanssen 2008; Wilhite 2005). This behaviourist approach to energy, promoted by economically advantaged individuals in corporations, governments, global organizations, and academic institutions, reduces humans to always-rational and choice-driven beings – overlooking the many people struggling to make it to the next day. It is as if the most critical element of decarbonizing energy stems from 'energy demands' that are inadequately adjusted to the amount of energy produced at energy plants and wind turbine parks at any moment in time (Mitchell 2010).

Even Nader's major social science contribution to the seminal report *Energy Choices in a Democratic Society* (1980) focused on public choices and consumption. The issue of decarbonising energy requires positioning as both the making of energy for collective use and also the making of technical adjustments in response to social and environmental problems, such as climate change (Günel 2019). It is striking that so much scholarship normalizes the energy consumption of the home-centred middle class and public everyday lives as the central issue in regard to decarbonizing energy. Meanwhile, there is a paucity of ethnographic studies either attending to energy in relation to industrial spaces of production (such as data production) or energy production from the infrastructural perspective of utilities and public utility workers. As Ballestero's (2019) ethnography on the condition of water utilities has shown, decades of financialization and regulative, neoliberal economic interventions have remade the logics that govern utilities to such an extent that labels of either public or private entities no longer effectively work to describe the internal relations and differences of contemporary issues such as climate change. The emergent complexity in relation to the organization of production processes within utilities is in dire need of analytical insights, which applies equally to both energy and water utilities.

1.2 Research question

The engineers of public utilities are using policy instruments and technological tools to effectuate a post-fossil-fuels future that realizes decarbonization. This work of planning

and construction coincides with the emergence of data industrialism, digital data, and the platforms and infrastructures taking up space in everyday lives and local neighbourhoods while consuming high levels of electricity. Meanwhile, Californian tech corporations are moving into all kinds of landscapes far from Silicon Valley (urban, suburban, and rural) to do business through their satellite offices but also to host their logistical centres. Commodities are packaged and sent off on the backs of platform delivery workers, and data is stored, networked, and analysed.

Writer and former tech worker Anna Wiener has commented in her memoir *Uncanny Valley* (2020): 'Tech, for the most part, wasn't progress. It was just business.' While a discussion of what distinguishes tech from technology, progress from the passage of time, and business from development would be interesting, this memoir of a tech development insider highlights yet another more pressing issue: what is the role of digital technology companies in the progress of contemporary societies? Perhaps to organize social life efficiently through digital means? Or to produce financial wealth for politicians to tax in order to distribute welfare goods, while offering jobs locally? Many stories have already been told about the vast global technology companies with their new business models and data analysis instruments. Yet not so many stories have been told about how digital technology companies become strategic partners of managers, leaders, and politicians in designing societies that promise both digital, data-driven community enhancement and decarbonization of technology use. And even fewer stories have been told from another insider perspective on tech development: the experiences of those who do not work for the companies but for the public energy utilities on which tech development crucially depends – both for supply but also for the decarbonization of the increasing energy consumption of the digital economy.

These infrastructural points of energy and data are linked through processes of *production.* This study thus addresses and answers a twofold question:

How is energy produced in connection with the reproduction of the digital economy and what effects does this emerging connection have on the utility work of public energy infrastructure?

The opposite could also have been a front and centre question: 'How is data produced through the reproduction of energy?' However, such a focus would have located data, data production, datacenters, and data work as the main research objects; instead, I have researched the work of public energy. But, as I argue, there are, of course, important lessons about the industry of data production to learn from studying how energy is produced in connection with the digital economy.

This research interest in energy production stems mainly from the fact that it has been partly inaccessible and ignored in studies of the digital economy. The energy issue of data production has largely been covered from the perspective of how much electricity and water is required by datacenters, data mining, and AI, as well as the impacts on local communities of activities such as water and land grabbing by companies and local governments. It has been treated more as an assemblage of numbers and facts that can be studied empirically. My point is that there are numerous aspects of the major energy complexes of storage, back-up storage, and analysis of huge digital datasets that, as new events in world history, have not yet been studied. By exploring answers to the research question, the thesis as a whole contributes to the literatures on energy decarbonization in STS and related fields by turning to energy production as a possible space of intervention that has largely been overlooked.

1.3 Contributions and contents

This thesis is a compilation organized into ten chapters, including the three original research articles, of which this introduction is Chapter One. Additionally, it presents the contributions of each article manuscript to separate scholarly bodies of literature, as elaborated on below.

Following this introduction, Chapter Two elaborates on the research site of the study. It starts in the city of Odense in which the ethnographic research was conducted and then moves on to broader contextual fields from the perspective of governance in Denmark. Chapter Three unpacks and discusses the methodology of the thesis, while Chapter Four focuses on the analytical strategy – an ethnography of connected infrastructures – and elaborates on the decisions and accidents that have steered the research. Chapter Five

addresses the analytical implications of the research by relating processes of production and reproduction. In this framework I trace the concept of 'reproduction' from studies of industrial relations into more recent feminist scholarship on inequality and machines beyond, before, and from within STS in order to take the findings to the empirical setting of 'energy production' and 'data production'. Chapter Six concludes the thesis by showing how industrial power is materially reproduced through the production of energy, which accompanies the continued expansion of the power of the data industry. This is followed by Chapters Seven, Eight and Nine of the original research articles after which Chapter Ten finishes up with a coda that suggests speculation should be practiced in many other social spaces besides industrial offices as it allows technologies to be reclaimed for collective use.

Based on this content, the thesis contributes to the scholarly literature on the decarbonization of energy by showing how Facebook is reproduced through its connection to the utility work of energy production, which complicates and interrupts efforts to decrease climatic emission impacts from the energy infrastructure.[1] As discussed in relation to the literature, the decarbonization of energy has so far been analytically treated as an issue to be addressed by the reconfiguration and connection of fuels, technologies, consumption, and data. Yet the space of production – industrial production and energy production – holds practices, politics, techniques, and strategies that are crucial to study in order to learn which hindrances are reasons for the slow societal decarbonization that characterizes most nation states.[2] The study takes district heating infrastructure into the light of welfare politics as it only works through public or collective management and regulation of profit and local, municipal responsibility. Decarbonization is also a question of welfare politics and welfare infrastructures and situating it as such is vital to realizing decarbonization at all. Studying the points of connection between such energy infrastructure and big industry, including the global

[1] The thesis uses the name 'Facebook' rather than 'Meta' as that was the name of the technology company during fieldwork, and additionally, because more people are familiar with it.
[2] The thesis as a whole does not delve more deeply into theories of 'the state' although I work with the term empirically in Articles 2 and 3. I have published elsewhere on the processes of standardization and aggregation as effects of state-led datafication. In Blankholm et al. (forthcoming) and Salling (2021) I make these arguments in relation to the topic of this thesis research, and I have worked on them simultaneously, yet these papers are on other empirical foundations and research sites for which reason they have not been submitted as part of the thesis.

data industry, opens up more contrasts than merely that between the two organizational entities of industry and utility.

The three thesis articles contribute to three themes in STS scholarship with the following conceptualizations:

1) *Industrial excess* to the scholarship on 'late industrialism' (e.g., Liboiron and Lepawsky 2022; Fortun 2021; Ahmann and Kenner 2020; Fortun 2012). By studying the work of making excess useful, as it is a material that connects processes of production and consumption, the article argues in favour of engaging with industries and utilities as bound together by the tool of excess rather than as equally industrial.

2) *Layers of reciprocity* to the scholarship on 'technoscientific capitalism' (e.g., Birch and Bronson 2022; Birch 2020; Birch and Muniesa 2020; Fourcade and Kluttz 2020). In showing how utility workers have dealt with a layer of reciprocity that has not been examined in the literature on the digital economy and Big Tech, the article suggests that there are multiple layers to the digital gift economy. Not only are users and technology companies connected by reciprocity of data and services at the platform level, politicians of the welfare state and technology companies are also connected by reciprocal relations at what we call the base level, which also enables the continued territorialization of the digital economy.

3) *Colliding scientific laws* to the scholarship on 'the sociology of knowledge' (e.g., Asdal 2014; Mitchell 2005; Latour 2007; Stengers 2005; Callon 1998). The article builds on Isabelle Stengers' writings on the constructivist practice of thermodynamics and the literature on the performativity of economics to argue that findings on the materiality and mobility of scientific facts also apply to scientific laws, shown in the analysis of how the two laws – energy conservation (thermodynamics) and economic competition (market dynamics) – collide in the engineers' utility work put into decreasing the carbon emission effects of energy.

The thesis argues that more scholarly attention should be paid to the knowledge, experiences, and opinions of utility workers who work towards reducing the climate

change impact of the everyday needs of electricity and heat of local communities. Such ethnographic 'utility studies' can identify 1) the practical difficulties in realizing decarbonization and 2) which industries with hyperscale energy demands are reproduced through which governance and business tools. The following section presents the research site of the study in greater detail.

Chapter Two: Research site

This chapter begins by presenting the historical background and important events in relation to energy infrastructure and data storage in the city of Odense, Denmark, before moving on to the national context of regulation and policy that has enabled these two infrastructures to emerge. The most urgent concern to the utility workers of the energy infrastructure in Odense is how to end the era of fossil fuels, so this brief history of the research site starts by unpacking the context of their concern.

2.1 Heating Odense, Denmark

Image 1. A building hosting a coal boiler in Odense on a cold day in 2020. Photo by the author.

On a Tuesday in early November 2020, the furnace of Block 7 was just about to emit smoke for the first time since the previous winter. The date for Block 7's annual start-up

was a topic most of the utility workers had discussed in the canteen over lunch over the past few days. When will it get cold enough for boiler preparations to take place? Many calculations go into finding the most suitable moment in the later part of autumn for starting the major boiler once again. Weather forecasts, most importantly, are crucial data for approximating when the block becomes a necessary unit in heating all the buildings in Odense, home to around 200,000 people and Denmark's third highest populated city behind Copenhagen and Aarhus. In November, the average temperature drops so low that incinerating garbage, burning straw waste from farming, and using electricity is not enough to heat the city.

Image 2. Map of Denmark and the location of Odense city.

Block 7 only burns coal but that is about to come to an end. Every year over the past decade, the heating engineers have worked to make Block 7's active season shorter and shorter. 2022 was planned to be the final year it would provide the energy supply in the 'firing season', as it is often referred to. It is the season when the city's heating system is not only necessary for producing hot water for its residents and workers' washing and

cleaning needs but, most importantly, for keeping buildings warm. The Danish winter is kept at bay in the city by heating homes, schools, shops, hospitals, factories, and offices via the pipes of the Odense heating system.

Block 7's annual ritual is followed with great interest from the offices adjacent to the old energy plant where the energy planning engineers' windows face the various blocks that are fuelled from a variety of sources. On this first cold yet sunny, blue-skied autumn morning – as many residents have turned their thermostats up a degree – the smoke is rising and hovers in the air over the large area in which the energy plant is situated. The rebuilding of Block 7 and the dismantling of its coal boiler is an event that the workers have laboured hard to realize. Ending the fossil fuel era in Odense has been a personal goal for many of them and it has taken countless hours to calculate different scenarios in which coal does not play a part, not to mention the numerous meetings in which others, such as city council members, had to become equally convinced that such a future was actually possible.

These scenarios come to life in excel sheets, exported tables, and in daily discussions among the engineers. Meanwhile, the production numbers on energy from the burning of coal are replaced with data such as the those indicating energy produced from the recently built energy station a few kilometres from the energy plant. This one is called TBV, short for 'Tietgenbyen', which is a new industrial area projected by the Odense city council. The energy plant is located in an older industrial area, which is home to a general scrap metal dealer, a car scrap dealer, an auto check company, and the canal which was originally built for colliers to carry coal to the plant. Tietgenbyen, named after C. F. Tietgen, one of the most famous industrialists and monopolists of 19th century Denmark, is located next to the national highway and is the official address of a range of new companies specializing in robot manufacture. It is also the location of the first Danish Facebook datacenter: the supplier for the newly built heat station next to it. The heat accumulating around the servers, like any other larger computer, is funnelled into the energy station, further heated by electricity, and then distributed to the nearby residential area.

Image 3. The first coal for the new energy plant located next to Odense Canal arriving in the cargo ship Myllykoski in 1952. In the first years of operation, one collier would arrive with enough fuel for the entire winter season. Source: Fyens Stiftstidendes pressefotosamling, Odense Stadsarkiv.

The work of making these two infrastructures meet was my reason for doing fieldwork with the heating engineers in 2020 when the trial phase of using the server heat was about to come to an end. The datacenter opened in 2019 with a direct connection to the energy station and thereby the total heating system of Odense. This type of urban and sub-urban infrastructure – 'district heating' (in Danish: *fjernvarme*) – is in 2023 the heating source for around 65% of all buildings in Denmark. The job of heating liquid for radiators, flooring, and plumbing needs carried out by engineers who are employed to maintain, extend, and plan for the future of the district heating infrastructure that transports a heated liquid (oxygen-free water mixed with caustic soda and colouring) through the pipes of the city onto its buildings. This contrasts individual heating technologies and systems, which must be maintained by building managers and homeowners.

In recent years, ensuring the delivery of heat to Odense's residents has not been the

only engineering concern. Figuring out how to decrease carbon emissions from the large energy plant that heats the water solution for the piping system has been both a personally important target for many of the engineers as well as an imposed trajectory due to recent national climate policy. The scenario calculations on how to make that happen coincided with the news of a Big Tech company purchasing local land to build a hyperscale datacenter. The critical search for a coal substitute made the engineers' endeavour of meeting with officials from Facebook not about *whether* to connect the two infrastructures but *how* to do so.

A few central Odense buildings were the first to receive district heating in 1929. A few years before, in 1926, the schools of the town of Svendborg, south of Odense, were some of the first to receive district heating in Denmark, although as early as 1903, a Copenhagen public hospital was receiving excess heat from local garbage incineration. A local engineer and his colleagues had been inspired by Svendborg and requested to purchase the excess heat from Odense Municipality's electricity-producing energy plant, and soon they began to direct the heat to more buildings in the city. In 1949, a new major national electricity plant was constructed in Odense that was to supply the whole of the island Fyn on which Odense is located.

Image 4. New pipes are constructed to connect more areas of Odense to the large new energy plant in 1952 – here at Ærøgade 22. Source: Fyens Stiftstidendes pressefotosamling, Odense Stadsarkiv.

In 1953, the plant opened with financing from local municipalities, electricity utilities, and funding from the later-closed Ministry for Collective Works (Ministeriet for Offentlige Arbejder). The latter was drawn from the Danish portion of the strategic aid offered by the United States under the Marshall Plan, sometimes also referred to as the European Recovery Program – and this was certainly not the last time that American strategic industrialism would come to influence local life in Odense. The Danish sum set aside for energy production was split between seven large energy plants. Such is the story in the book *Collective Voltage* (in Danish: Spænding i fællesskab) written by two local historians commissioned for the 50-year anniversary of the energy plant (Dyrbye and Thomsen 1999).

Image 5. Odense's energy plant photographed between 1968-1970. It has since been extended with several boilers and buildings. Source: Odense Stadsarkiv.

Fynsværket (in English: Fyn energy plant), as the plant was named, is to this day the delivery centre of district heating in Odense. This was especially the case after electricity production from burning fuels was downscaled in the 2010s and the municipality-owned Fyn District Heating (in Danish: Fjernvarme Fyn, FDH) began to

accept excess from electricity production, undertake daily management, and retrofit the old energy plant for the future of decarbonized district heating in Odense. After a few decades under the management of the Swedish state-owned energy company Vattenfall – through which district heating had been publicly managed, mainly as excess from electricity production for the Nordic grid – the energy plant once again came under municipality ownership in 2015. This complicated organizational history makes it apparent that district heating is much more than merely an energy plant and a chosen heating solution; it is equally about energy production, as it represents energy distribution through the major pipe network that by 2023 has come to service the total city. During these decades district heating has also increasingly come to depend on a range of solid fuels like garbage incineration and straw. Finally, when the Facebook datacenter construction was initiated in 2017, the use of server air was announced as a means for phasing out the coal that had been central to the energy plant since its construction in 1949.

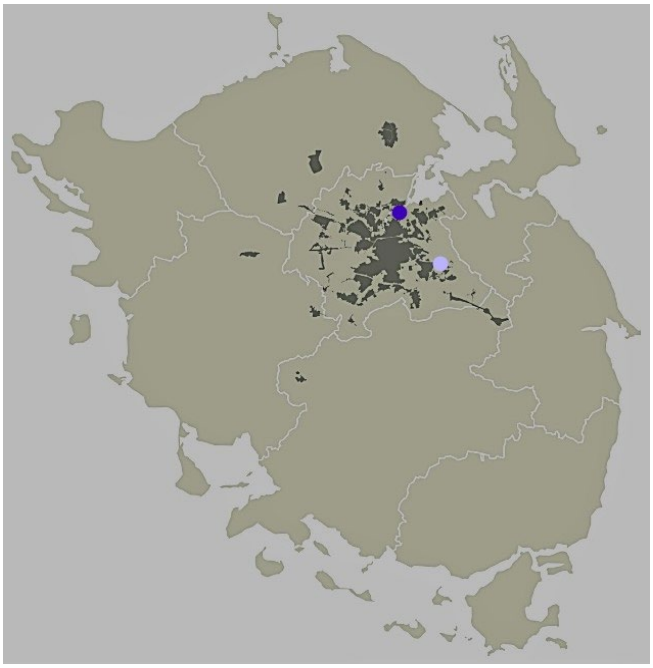

Image 6. A map of the island of Fyn (in light green) is an edited reprint from FDHs 2022 publication document for visitors that shows (in dark green) the area covered by FDH, which is all of Odense city. Beyond the major energy plant (former Fynsværket), the district heating is also produced from 25-30 smaller energy plants located in corners of Odense. One of these is the new heating station built next to the Facebook datacenter in southeast Odense, Tietgenbyen (violet mark), located 11 kilometres from the central large energy plant by the harbour in North Odense (purple mark).

2.2 Storing data

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A landscape shot of boxy, concrete architecture recorded by a drone. Dramatic piano music plays during a cut to a dark room that is slowly lighted up to show computer servers in operation. 'My first thought was "wow", is it really happening that Facebook is coming to Odense?' says the Odense mayor. A person walks through the server corridors with a laptop on a rolling table. 'It's easy to say that it was a great champagne moment', the municipal manager for the business area comments while filmed at a pier. Then the site coordinator at the Facebook datacenter in Odense is also interviewed: 'The fact that Facebook would come to Denmark - I think - that was just an amazing opportunity.' Cut. Another datacenter employee, the environmental, health and safety coordinator: 'To be honest, I knew they were building something here, but not this size or magnitude.' A person in a yellow security vest and safety helmet carries a load of materials with Facebook name tags in a corridor, seemingly within the datacenter. Another shot from above carried out by a drone. The music gets more intense as the camera moves over the outside walls of the datacenter from above. Think Christian worship choral ensemble music as it is used in sci-fi films to signify a majestic, over-worldly event has taken place (such as in the fictional tv show 'Devs' from 2020 about quantum computing). Facebook logo's layered on top of camera shots. The datacenter and cars parked outside surrounded by shiny, new green grass. It is sunny. Light-hearted guitar pop plays while a person is walking into the canteen of the datacenter where a lot of people are already eating. Someone grabs a slice of pizza from the buffet.

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These are the first 45 seconds of the 3 minutes long commercial video 'Facebook's new home in Odense' that is posted on the website in blog format 'Tech at Meta.' A range of people are interviewed, for example the director for FDH and a professor in energy engineering from Aalborg University (also in Denmark) that is very excited about the prospects of collaborating with Facebook. The video was made for the opening of the datacenter as it was posted on the Facebook page for the Facebook datacenter by its first day of operation in 2019.

After years of negotiation and construction, the datacenter opened with a festive event

for which all the prominent Danish newspapers and tv stations were invited. The first construction plans were published in January 2017, only a while after Odense Municipality and FDH was informed which tech corporation that was to open a datacenter. During the negotiation process, who they were dealing with had to be kept secret due to non-disclosure agreements (NDAs) that were signed before Facebook had made any decisions on purchasing land in Odense.

The original price for 508,000 square meters in the south of Odense was 68 million DKK, approximately 9,1 million euros paid to the municipality. After the official opening, Facebook would come to build on more of the surrounding fields and extend the datacenter – or rather 'Cassin Networks' would, which is the name of the Danish daughter company that Facebook would establish as another daughter company to its international operations company established in Dublin. Yet the land acquirement and datacenter construction would turn out to be just the start of Facebook's infrastructure interventions into Denmark.

2.3 Governing district heating production

District heating is a result of deliberate national and municipality planning, policy reforms and organisational interventions. To this day, the utility workers' engagements with building and imagining future retrofits both depend on navigating and following policy and expected-to-come policies. The district heating infrastructure in Odense is managed by an organization, which is legally an 'independent public company'. In Danish: 'selvstændig offentlig virksomhed'. The most appropriate title in English for such a formal governance structure is 'state-owned enterprise', but instead in this case is it 'municipality-owned'. This formal structure particularly emerged in Denmark in line with new public management and neoliberal economics. The Ministry of Finance describes the form as the following: 'The state in many cases uses the enterprise form as organizational frame for activities with business character because critical opportunities are expected from market orientation and competition exposure of activities that formerly were managed by the public state.' (Ministry of Finance 2023)

The statement solidifies recent governments' formal devotion to the logic of efficiency

outcomes from privatisation but the story of district heating is another than the general ethos of neoliberalisation. Yet the form of organisational arrangements around the public ownership, independent management model reaches much further back into history.

All the largest district heating systems in Denmark are organized as independent public companies that act as corporations in terms of budgets, investments, innovation and economic management. Their main governing principle is restriction from profiting from selling heat to the local citizens to ensure the district heating heat is the cheapest possible heat source. This principle is one of the guiding empirical examples that point to how energy systems in Denmark are (still) governed as 'welfare-providing infrastructures' even when they are increasingly marketized. A opinion piece by the director of the Danish sector organization for district heating (Dansk Fjernvarme, a form of industry union) started off with the following sentence: 'Utility is a condition for creating welfare, growth and development.' (Dansk Fjernvarme 2019) District heating is, despite the ownership form, functionally a municipality infrastructure. It is mainly built and maintained through 1. Regulation on municipal responsibility for including heat networks extensions in new local planning (in Danish: projektbekendtgørelsen) (Ministry of Climate, Energy and Utilities 2021), and 2. Regulation on the district heating utility's internal activities, including prices that are adjusted for maintenance, fuel and technology purchases and salaries but always remain non-profitable (Ministry of Climate, Energy and Utilities 2020).

Whereas district heating has over the years come to depend more on its own regulation and laws, it is still an energy form that heavily depends on electricity regulation. As electrification of all systems, including heating systems, is in global energy governance generally viewed as an entry to lower emissions through increased renewable electricity production, district heating currently relies more on electricity again. And the privatization interventions on electricity that has dominated since the 1990s continues to impact heating systems.

	1920s-1970s	1970s-1990s	1990s-2019	2020
General conditions	District heating pipework is built and extended in the cities first from excess heat from electricity producing engines then also from garbage incineration	Oil crisis and fuel scarcity, district heating is extended not just as leftover infrastructure but as means for efficient fuel use	First energy regulation with focus on carbon emissions: energy taxes and subsidies for renewable energy construction and production	Electricity prices drop low due to increasing renewable energy integration + tech companies open hyperscale datacenters and become another industry delivering excess heat
District heating regulative interventions	Largely unregulated and unsubsidised	The first law on heat utilities, including centralised responsibility for planning and non-profit prices	The tax on industrial excess heat to ensure more efficient use of fuels + the second law on heat utilities, including municipal local responsibility for planning	The Climate Act (2020) eliminates tax on industrial excess heat and replaces it with an energy efficiency scheme
Policy rationale	District heating depends only on excesses	Limit dependency on oil import and ensure equal access to cheap heating	Decentralise responsibility to fit local needs and expertise and thereby speed up district heating extensions	Increase renewable electrification to lower carbon emissions from the grid

Figure 1. A brief history of Danish district heating regulation events. The climate act and tax on industrial excess is elaborated on in article 1 of the thesis.

Liberalization of energy production is one of the globally most general policy trends in the transformation of energy systems - in Denmark and within the context of numerous other nation-states. Obviously, liberalization opened energy systems to economic competition involving more non-state actors in the governance of energy systems (Magnusson 2016; Rohracher 2010). Market-based logics and economic instruments have ruled energy networks since the first systems were planned, and the global trend of deregulation of energy generation only intensified the implementation of such logics (Mitchell 2011). This situation was also intensified by policy introduced through the EU to create a single market for electricity and gas (Silvast et al. 2021). The literature on the performativity of energy markets argue that these initiatives are not in opposition to regulation, and most energy systems are in fact regulated in areas such as pricing, quality and security of supply (Silvast 2017; Bolton and Foxon 2013). Policy, in other words, is used as an instrument for 'market design' but is not in clear opposition to a market-based system (Doganova and Karnøe 2015). When renewables were first integrated into energy systems, this happened through policy. These sources were expected to compete with fossil fuels and infrastructures that had dominated the energy

supply for decades. However, European governments soon realised that these markets were hostile to commodities that were identified with values other than economic profit, such as decreasing carbon emissions (Karnøe 2010). Consequently, the major introduction of wind power – to make an example – became dependent on governance instruments such as 'feed-in-tariffs' that gave renewable electricity competitive advantages over fossil fuels (Pallesen, 2016).

These policy trends of energy market design and ownership privatisation had many effects, such as the formerly state-owned energy company Ørsted that after a decade of parliament negotiations was partly (19%) sold off to investment firm Goldman Sachs in 2013. The official argument by the politicians responsible for the sale was to ensure more foreign capital for the construction of offshore wind power. While district heating utilities has not seen the same privatisation interventions as electricity, minor local interventions at municipality level have experimented with liberalization particularly in relation to external consultancy and marketing (Iuel-Stissing and Karnøe 2018). Privatisation potentials of district heating was once a debated topic in the Danish parliament yet was largely abandoned in the mid-2010s. Municipalities and thinktanks came to successfully argue for the continuation of local, collective ownership. This was backed up with analytic conclusions on how recent years' privatisation of heating systems in Sweden and Germany had in contrast to Danish systems overall not resulted in lowered prices nor intensified decarbonization (Cevea and Grøn Energi 2015).

2.4 Governing Facebook data production

In contrast, the digital economy has seen almost no sector-specific regulations, particularly with respect to the energy hungry data centers in areas governed by municipal, regional and national actors (Vonderau 2019). In Denmark, apart from data specific regulation such as the European Union's General Data Protection Regulation (GDPR), tech companies are regulated like all other industries in relation to taxation and energy use. Despite the non-existent regulative intervention, Danish politicians and governance institutions have been involved with a range of formalised political discussion initiatives, writing manifestos and doing official political analysis on Big Tech.

In November 2021, the Danish Government published a white paper on Big Tech based on a collaborative effort between the Ministry of Culture and the Ministry of Business, Industry and Financial Affairs. With the title 'Towards a better social contract with big tech', the report elaborates on contemporary concerns. It presents statistics on the economic power of technology companies, how they have evolved and how their 'net value' calculated in GDP positions the companies in equal power and economic status to major nation-states such as Brazil and Italy. Beyond the statistical analysis, the highlight of the paper is its nine principles, a form of manifesto:

"1. the business models of big tech must be subject to democratic frameworks, 2. children and young people must have a safe childhood with a healthy balance between the digital world and the physical world, 3. big tech must support democratic debate – rather than undermine it through digital echo chambers and polarisation, 4. big tech must take greater responsibility for the content on its platforms, 5. free, well-functioning media must support democratic debate, in which everyone receives fair payment for their creative work, 6. workers' rights must be protected – including on digital platforms, 7. big tech must contribute to the financing of the welfare society in line with all other companies, 8. competition must be fair and transparent, and consumers must be able to shop safely online, 9. democratic governments must set the framework for big tech – not the other way around." (Regeringen 2021, p. 6)

The principles show that Danish politicians are indeed interested in regulating Big Tech, however the bureaucratic governance infrastructures struggle to deal with these companies as different than any other company that 'must contribute to the financing of the welfare society.' Yet the meaning of the word 'social contract' itself, as originally elaborated on by Rousseau, somewhat contradicts the regulative aspirations with its opening for building a moral and political codex rather than a legal one. The strategic approach to Big Tech has in recent years by Danish ministries been called 'techplomacy' (Office of Denmark's Tech Ambassador 2023). It is a term made to capture the decisions on dealing with major technology companies as with nation-states through geopolitical diplomacy, collaboration, and hopes for democratic influence. As it is standardized in geopolitical strategy management, the influence hopes of techplomacy

constructs it as the only option in contrast to authoritarian sanctions, boycotts and means of avoidance (Fejerskov, Schott, D'Ignazio and Klein 2021).

This whitepaper goes deep into the power of Big Tech within Denmark without mentioning datacenters and local initiatives. Exactly this point speaks to the extent to which platform governance and critical infrastructure governance are treated as separate areas - of which the first is positioned as a more urgent issue. In another report from 2021 called 'digitalisation of the climate battle', a Danish national commission for digitalisation (named SIRI) outlined their suggestions of the most important and effective efforts for the coming years within climate and IT. This commission was initiated by several politicians, the Danish engineering union and professionals from the IT industry to discuss tech innovation's role in society. Whether the motivation of the report is to use digitalisation to reduce carbon emissions or reduce impacts from digitalisation is unclear, perhaps both.

A section within the report writes out the recommendation to analyse areas in Denmark that would be suitable to construct datacenters both in terms of conditions such as good grid connection and high security but also what is referred to as 'heating capacity'. In other words, whether the area is located close enough to a district heating system. It also states that datacenters make huge potential for district heating - half of the estimated datacenter capacity in 2030 could be utilised to replace fuels for 10% of district heating in Denmark. Not all datacenters are operated by Facebook nor Big Tech but in the report all datacenters are framed as simple as, datacenters. Notably, datacenters can be both overgrown in-house server rooms and hyperscale, global factories. Odense is an example of such 'heating capacity' that has been realised however with many more complications and effects than the report smoothly outlines on such potential relations between major technology companies and district heating utilities.

Chapter Three: Methodology

This chapter outlines my research process and the methodological contribution of ethnographically studying connected infrastructures. First, I go into documenting how the material was generated and then I discuss my methodological framework. There are many parts of this methodological framework that are classical to STS, with the focus on a specific infrastructure: district heating, and classical to anthropology, with the focus on a specific group of individuals: utility workers- of whom most are professional engineers. Yet I will come to claim that my central ethnographic focus is not the internal activities and 'the cultures' of the group and infrastructure. It is rather on the work practices of the groups and infrastructures that make district heating work and make connections with surrounding and imposing infrastructures of the digital economy. 'What really happened during fieldwork' can always be told in a multitude of ways of which some are more or less formal some more categorical, philosophical, situated or embodied (Traweek 1995). The following is one such choreography that documents the research process somewhat chronologically.

3.1 Initial questions

My ethnographic prospects started with intention to study Big Tech's role in phasing out fossil fuels, particularly in the setting of district heating - how do utility workers' aspirations correlate with Big Tech's sustainability engagements? And do they correlate at all? Due to my former research engagements with district heating infrastructures and the engineers that build and manage them (master's research), I was aware of the difficulties of enacting the desired futures for these infrastructures. Not many fuels suitable for district heating have the potential to fully actualize the desire for limiting carbon emissions. When Facebook in 2017 announced that it would place its first Danish datacenter in Odense, the connection to the local district heating utility was one of the core components of the press releases. While I was aware of the enormous electricity and water consumption of these hyperscale datacenters, as most people engaged with any form of energy politics are, the datacenter promised to make up such a new fuel that had been difficult for district heating engineers everywhere to acquire.

The research project *Welfare after Digitalization* had given me the responsibility to

study the subarea of local governance practices in the era of mass-scale digitalization of welfare societies.[3] I decided to conduct this research with a somewhat unconventional perspective on digital social life as I would investigate the infrastructural effects of digitalization rather than deliberate digitalization projects and platforms. In other words, studying digitalization where digitalization was just a fact and not a concern in itself. In the Summer of 2020, I sent an inquiry to the contact email of FDH to request conducting fieldwork with its utility workers. At this point, with the awareness of having three years to conduct the total PhD research and thesis, I was already constructing limitations to the study. By pursuing thorough insights into the utility work the potential for other ethnographic insights were deliberately let go. For example, this thesis is not informed by material from and with local citizen and user perspectives and experiences.

3.2 From Big Tech in Denmark to Odense and Facebook

Having spent a few months reading the available publicity material and news articles about these new datacenters in Denmark, I had learned that only one datacenter had managed to connect itself to a local district heating infrastructure even though more were expected to do so when first announced in 2017. During one of my first interviews before entering FDH, a consultant from the industry organization Danish District Heating, told me that none of the other Big Tech datacenters had succeeded in delivering server heat in their locations, of which the largest problem was that most datacenters were placed too far from local district heating infrastructures. If the pipes from the district heating infrastructure in the city of Aabenraa connecting households, the energy plant and local institutions, offices and factories was to be extended to reach the potential new Apple datacenter, then the hot water running in the new pipes would not stay sufficiently warm. The datacenter was placed too far away from the underground district heating pipes. In Viborg, an unsuccessful case of an Apple datacenter was a result of discussions around which of the possible district heating contractors should receive the server heat delivery. Suddenly, with the emergence of datacenter server heat, two local energy contractors were put up against each other in deciding on who should manage the changed infrastructure of district heating as the

[3] The research project was enabled by the Velux Foundations [26584].

result of this new heat.

Odense's heating infrastructure and its Facebook datacenter infrastructure became the central site of my study partly because none of the other promised datacenter-district heating connections were successful to many commentators in the heating sector's large disappointment. I wondered, what had they done differently in Odense? And where do these infrastructures now connect?

3.3 Engineering knowledge, ethnographic knowledge

[T]o speak of generalities is to speak through specificities. And vice versa.
- Marilyn Strathern (2002, xvii)

Fortunately, my email query for FDH was answered with much interest in my proposal. The manager for the development division and the manager for the HR division in FDH set up an online meeting for which I was invited to nuance my research interests and my methods of working. Our meeting took place in start-September 2020 when many institutions were still in Covid-19 lockdown. We spoke on Zoom, about who I could follow and where I could be placed during the fieldwork period. It was settled that for two months I would be located in the section of which my contact person, John, was the manager for the group of engineers planning the future for FDH. From there I could meet and visit other employees and sites of FDH. In early October I visited FDH for the first time, after which I for two months would participate in the daily work of its employees in workdays from 9-17. Most days I would stay in a rented room in Odense and sometimes I would commute to and from Copenhagen. I was given a desk with the engineers in the development division, a laptop and an email address. All things that was standard to supply interns with during their stay. Through the email I got invited to lots of meetings by a variety of the engineers in the division but also by employees from other parts of FDH that John had set me up with, others I had met during lunch or been introduced to when walking through the energy plant or its annex office building in which the development division is located. Sometimes John would inform me right before a meeting about the content and ask whether I wanted to join which was obviously always the case unless I had something scheduled with other utility workers.

However, some of the most inspiring ethnographic moments came about from sharing space with the engineers on a daily basis. If I had nothing scheduled I would spend my time writing up fieldnotes and reading through reports, FDH news, books, articles and all other such documents that I was either given in print or given access to.

Much collaborative work would take place in this office space. Often someone needed a colleague's input on a scenario analysis for the fuels of the energy plant in the next 50 years, someone has just read the last news about some energy policy and needed to vent, and at another time someone was preparing a presentation about heat pumps and wanted to show me which slides they were thinking of using. Often, such desk space conversations would come about as one of my deskmates would suggest I look at something that might be interesting for my research. To my surprise, it seemed I was rarely in the way but someone that my interlocutors enjoyed sharing information and concerns with. In that sense, due to their active reoccurring involvement of me into their work practices, I did not have to put much strained effort in to ethnographically *generate materials* through our collective interactions rather than *collect data* (Whatmore 2003). Such generated material is knowledge that comes from the situations in the ethnographer make partial, fractal connections (Strathern 2004 [1991]). These interactions and connections I would document through fieldnotes in an A5 size notebook that I would bring everywhere, take photos, and receive reports and emails based on our conversations and experiences. What I present and analyse in this thesis is ethnographic knowledge that has come about through the relations that I have made with my interlocutors, and the ways in which they have actively, continuously involved me in their daily work.

The limits to which kind of knowledge that is a potential outcome of ethnographic research are not settled but they have been experimented with, changed and adopted since the early days, the start-1900s, of the anthropological discipline. One of the recent remarkable turns in ethnography is the portrayal of how research is not conducted in solitude. The practice of 'antihero care' is doing research without aspiring to be a hero either during fieldwork, in writing it up or acting upon it, which is a practice that opens the researcher to learn from others rather than describing others (Yates-Doerr 2020). As Isabelle Stengers (1997) notes, it is a question of how to 'speak in many voices.' I was

fortunate in the sense that the engineers were so keen to absorb me into the world of thermodynamics, energy planning and the mechanics of everyday energy infrastructure. It allowed me to engage with them through their material knowledge and practices rather than fieldworking for the observation of cultural aspects of their work.

Ethnography requires attunement but there are no ideal, perfectly trained, experienced ethnographers (Günel, Varma, and Watanabe 2020). Every new fieldsite requires ethnographic adjustment to its inhabitants. It became easier for me to follow the conversations on heat pumps when I didn't have to interrupt with questions like 'what is a COP?' (*co-efficient of performance* is an energy efficiency measuring scale). I could make meaning of the events and conversation of which I started to partake in when I could sufficiently 'step in' to the context (Chiseri-Strater and Sunstein 1996).

Getting from fieldwork to writing up required much in itself, but there is a learning in the difficulty of attending to, collecting, comparing and attuning to the fieldnotes, interview transcripts and 1000 pages of documents without simply saying what the engineers told me. For example, a problem for district heating utility workers is that there are no actual fuels that at present can decarbonize the infrastructure as much as they want. The learning concerns the qualities that studying the topic of district heating and data industrialism through ethnography offers. Ethnography is not a method but concerns a total research process, a form of viewing, scoping, attuning and sensing worlds through engaging with situations in a radically empirical manner (McGranahan 2018). When the research project was initiated no one else had studied district heating in Denmark or datacenters and heat delivery ethnographically. In that sense, moving from information ethnographically documented to analysis ethnographically documented – from generating materials to telling materials (Pryke, Rose, and Whatmore 2003) – was a trajectory I had to formulate as a research responsibility.

I end this section of the methodology chapter with a few points on positionality. Studying the connection of infrastructures highlights positional difference. I argue my ethnography involves relational tensions on two central points on positionality: 1. The relative space from which the study is conducted, 2. The production of naiveté. On the first position, studying these infrastructural connections is not a protest ethnography,

not one of holding perspectives and experiences in tension between but rather holding experiences in tension within. In other words, the utility workers already experience enough tensions (I don't need to bring them) in relation to 'the state', 'the technology company' and 'the climate crisis' – that I have been able to explore and build on. As I have brought myself and my own experiences but not the central tensions of the ethnography, I have also not needed to 'balance out' the ethnography by doing ethnography with Facebook workers - which besides that also would have required whole other means, negotiation and limited use of document materials The same goes for my reason for not doing fieldwork within the rooms in which policy was planned and passed.

On the second position of naiveté, the production of relative identities through affirmed difference can create access, integration, and excitement. While getting on with the fieldwork once I was enrolled into the daily work practices was not the toughest part, then first off convincing new interlocutors of my genuine interests in the political transformation of district heating indeed required some real effort. Formally, I was let into FDH with the contract of an intern – the secretaries already had such a form that could with a few edits fit the purposes of my stay during the fieldwork. The intern contract allowed FDH to have me accept with signature the limits to my formal access: which data I could not use, such as confidential daily production and consumption numbers and the practice of ethical conduct. Informally, the intern role proved to be of benefit in learning from and shadowing the utility workers. I was told several times, such as in the canteen during lunch, i*t's good to see that some young people care about district heating*. And when I was asked about my background and mentioned my master's research on district heating and a former student job at the Danish Energy Agency (sub-organisation of the ministry) I usually earned some respect – I was not here to learn from anew but to continue nurturing this novice interest in a new setting. FDH only had a small minority group of women workers of whom most were in secretary, accountant and environmental overview jobs. To which extent my appearance as a woman in her 20's within a group of mostly middle-aged men made the fieldwork what it was, is impossible to answer. Yet what I can conclude is that I always felt comfortable, respected and welcomed but also that the friendly and curious naiveté was possible because of how I was positioned as intern and how I positioned myself in

order to show respect to the expertise of my interlocutors and to learn as much as possible. Anyway, what is the ethnographer if not a novice of how practices are commonly situated and infrastructured?

Despite the scientific responsibility to communicate openly about results as part of ethical research conduct, it is not always clear to researchers how scientific results on political matters will be received until interlocutors do in fact receive and comment on them.[4] When my interlocutors at FDH asked me to come back to present the results of the research, I realized that not only was it a task put upon me as a researcher to work analytically with the empirical material. But producing ethnographic knowledge as it became contrasted with engineering knowledge also turned out to be requested by my interlocutors. When we discussed the preliminary results in September 2022, after my presentation, my heart could finally take a break from racing when I was told the context and details of district heating in Odense and in general were apparent in this more generalised overview that I had analytically presented - the connections that stick out of the infrastructure as well as those politics that journey from the outside in. Hopefully that judgment has somewhat survived the finalising rounds of writing the thesis.

[4] A few additional points on decisions in relation to ethical research conduct: All names of individual interlocutors are in this thesis pseudonymised with the argument of constructing limited personal traceability. I attempted to inform my interlocutors of this decision verbally during fieldwork as I had not been required by research oversight nor university legislation to produce consent forms or an information sheet. Yet I was required to document safe storage of data, which I approached by keeping fieldnotes in notebooks in my locked office and deleting audio files after transcription then stored on a local drive. The request for conducting fieldwork within FDH was accepted with a mutually signed agreement, handled through a form of 'procedural ethics', and the fieldwork beyond the agreement was carried out through 'ethics in practice' (Guillemin and Gillam 2004). The fieldwork did not generate sensitive personal data, and this was also not the ambition of the research, yet the formal agreement required me to not distribute any form of data on daily production and consumption numbers, such as how many Giga Joule a specific person had consumed or how much energy FDH had produced on a certain day.

3.4 Empirical connections, or studies I did not do

The approach to ethnography (that I have both employed but also found myself practicing without moments of epiphany and initial deliberate decision making) emerged in the ethnographic tradition in the 1980's as response to global organisations' efforts into making tools of government travel far and wide in the name of development (Wahlberg 2022). When I in 2019 read in an online newspaper article that the new Odense datacenter had been connected to the historical district heating infrastructure, my interest in the infrastructures already came to exist at a certain scale: an infrastructural scale, rather than at other common ethnographic scales such as organisational, cultural, and individual containers of meaning-making. This infrastructural scale is made through the dynamic relations between things and people that participate in the constructing the infrastructure and thereby also its own scale (Mol 1999). STS is a field that demonstrates how scientific knowledge is *multiple* but is simultaneously *one kind of* knowledge in relation to other forms of knowledges in which specific people are experts in. In other words, I see it as an attempt to undo knowledge hierarchies through attending to already-existing differences in the wild. The following demonstration is based on responses to presentations and conversations *beyond the field*, such as with colleagues at conferences, family members, people I have met at bars that asked me what my research is about, journalists, etc. I cluster those immediate responses to my what goes on in my field within the following groups to set the scene for what I actually did do in my analysis:

<u>Responses</u>:

A. *how smart, problem solved*

* leaning towards: 'technological determinism' and the causal explanation between technological development and societal progress (Wyatt 2008)
* lacking: determination for ethnographic curiosity and unfolding experienced complexity

B. *facebook is no more than a parasite on the Danish state*

* leaning towards: 'god's eye view' and the application of theory before studying (Haraway 1988)

* lacking: determination for ethnographic curiosity and unfolding experienced complexity

C. this thesis: *how interesting this new form of connection between public utility infrastructure and a major technology company - how and why do they do make this connection, and what are the implications?*
* leaning towards: practical ontology (Gad, Jensen, and Winthereik 2015) and the practice of resisting the academic urge of closing down analytical points too early in the research process
* lacking: application of theoretical framework before ethnographic fieldwork and taking strategic explanations by powerful companies and politicians as the only appropriate description of 'what is going on' in the field of study

Obviously, response A and B are caricatures in the sense that many people whom I have talked to about this research have also had more nuanced responses. But they are also literal sentences I have heard when conversing about this field. Response A and B attend to different scales. A attends to the scale of carbon emissions from the energy plant in Odense. B attends to the scale of democratic sovereignty over infrastructures. Curiously enough they are often mobilised as counterpoints. The interesting point is that response A and B only exist outside my field as none of my interlocutors practice these kinds of closures. That is because such practice is not an option as they are living with and daily dealing with the complexity of the infrastructural work at multiple scales.

This take is more than anything practically ontological as it arrives with a concern for how agency is produced through material things rather than a scientific ambition with mapping and representing where material objects inactively sit (Jensen 2021; Gad, Jensen, and Winthereik 2015; Cussins 1996). In other words, the tradition that comes from the ontological turn in the humanities and social sciences of the late 1990's lives on but is also challenged in this infrastructural research. The ambition is radically empirical (Gad and Jensen 2016). And it is flexible to occurrences and events in the field that might fully turn around or be of surprise in contrast to any research point as such flexibility is considered a higher academic standard of quality than that of traditional academic validity measures such as attempting to prove the durability of an analytical

point (Papazu 2019). I want to demonstrate practical ontology as it is a practice that requires constant resistance to academic know it all-ism – more of an attitude to research than a method (Gad and Jensen 2010).

Such responses as A and B – on top of how they attend to different scales - would prove restrictive analytical strategies in approaching the major concern of how to use server heat to phase out coal while maintaining the district heating infrastructure. These conversational responses position the analytical decisions closer to an analytical attitude rather than any form of deliberate analytical strategy. However, I did eventually come to decide on and reflect on the form of the research decisions. The following chapter discusses the analytical strategy through the development of a research protocol for the study of connected infrastructures.

Chapter Four: Analytical strategy

Researching not *about* infrastructures but instead *through* infrastructures has cut the analytical field of this research in certain ways. Infrastructures, like assemblages and other extensive forms, are more stretched than practices and less stretched than far-travelling, major problematised complexities (Wahlberg 2022). Infra is also translated to *under.* As in underground, underneath, underpinning or understated. They are means for connecting but not the goal, the problem, nor the material that is engineered to travel.

How long are infrastructures? Where do they end? And how do infrastructures become connected? This protocol attends to locating infrastructural boundaries because they are constantly remade. It starts from the point that research is always done from a position located more within or with concern for some infrastructures than others. Simply because research is always situated more in some locations than others. This point is important because studying connected infrastructures 'from above' is impossible as it requires a 'god trick' in which everything that takes place in the field can be glanced at equally (Haraway 1988). While I want to see how the infrastructures (district heating and data storage) extend and connect a variety of points in the world that they make, I also want to see how these networks of pipes and cables are cut (Strathern 1996) as the boundaries of and within them are negotiated and changed (Star 2010). Because they are indeed cut, closed off, punctuated, and transformed. Locating the ends to infrastructures enables locating engineered infrastructural points of connection. The district heating infrastructure both produces, is produced by and connects a range of other infrastructures, which is a mess that is impossible fully to represent in analysis. Boundaries are both made in the field and by the ethnographer, and early on I realized I had to make decisions when 'writing up the infrastructure'. The protocol I present in this section resembles it.[5]

[5] The protocol and documentation of the analytical strategy was developed as part of a PhD course based on the book *Experimenting with Ethnography* (Ballestero and Winthereik 2021)

4.1 An ethnography of excess

When analytically locating the ends and boundaries to the infrastructures have turned out difficult (where does the datacenter end and how far does it stretch into the district heating?), I have turned to excess as a material that is let out – to show: *where* is it let out? And why? Studying connected infrastructures depends on excess. It is the space between boundaries made to demarcate what is too much and what is made necessary. 'Excess' is a term that is unfolded further in article 1 as it is the 'excess heat', hot air from servers', that bind the datacenter and district heating infrastructures together in this instance. After spending time discussing the excess of excess heat and how to use it with my interlocutors, I became concerned with how spaces of excess make possible a look into how necessities and unnecessities are made and by whom. To the ethnographer studying infrastructures, excess is the space in analysis that she does not immediately know how to articulate and organise (McGranahan 2018). It is a space in between stabilised points of information. Infrastructures are constantly reorganised, retrofitted, extended, repaired, dismantled or left to decay as they are abandoned. Where are valves, knots, transmitters, gates, translators and ends installed to manage the converged production of necessities?

Take chemical infrastructures: pipelines that travel across long distances from production industries to other industries and to areas in which some people have decided that the chemical products are useful for one or the other form of fabrication (Murphy 2013); and toxins with generative compounds to chemically-made everyday commodities that simultaneously make rivers flammable and undergrounds contaminated with fluoride for more centuries than the industries (even fully aware of the violent effects of their operations) often could have projected (Murphy 2017).

To de la Cadena (2021, 2014), excess is the space beyond ethnographic knowing. That which comes after the knowable limit that is always produced both within the field and by the ethnographer. Excess is generative as it allows for the ethnographer to practice an ethnography that is less concerned with knowing it all, representing it all, and telling a universal story (as it is impossible even though some may claim they do it), and more attentive to how boundaries are produced. An example: In her analysis, it is an Andean mountain that is made invisible through the bureaucratic boundaries to what counts as

a ‘being’. Parts of de la Cadena’s ethnography on bureaucracy struggled with locating and ‘seeing’ the Mountain for what it was, such as to the people that lived with and off the Mountain, which made clear how points of unknowing (can a Mountain be a being?) were necessary in attending seriously to the world of the interlocutors. This unknowing is what in her ethnography is referred to as excess. The following paragraphs are inspired by de la Cadena’s attention to ontologically produced boundaries but turns more specifically to the study of infrastructure production rather than knowledge production. Pulling knowledge and infrastructure apart is of course impossible (as infrastructures make knowledges and knowledges make infrastructure), but I think it matters which things that analytically are placed in the foreground and in the background. As infrastructures are often a lot more tangible and material, knowledge production is probably a lot easier to study through infrastructures than the other way around.

Building on Star and Ruhleder’s (1996, p. 112) seminal question within the study of infrastructure ‘when is an infrastructure?’, Carse and Kneas (2019) have asked ‘when is an infrastructure finished, and when would we know that?’ Much of the drive within this framing is resembled in the scholarship interested in unfinished and unbuilt infrastructures. As Guma (2020) necessarily argues, centering infrastructural ‘incompleteness’ is necessary in countering developmententalist approaches that assume infrastructures for example in the Global South need to resemble – what is considered similar – infrastructures in the Global North: that infrastructural universality across locations is a sign of wellbeing. I build on this as I have experienced in the field of district heating and datacenter connections that my interlocutors never think of the infrastructures on which they work as ‘complete’. It might make sense to extend the pipes: if buildings are close enough so the heat within the pipes will not become too cold while travelling, if building managers or homeowners sign up for receiving district heating, if the energy plant produces enough fuel, and if the municipality supports the extension. However, as the focus here is the connection of infrastructures within one location, the initial reason for connecting the pipes between the two infrastructures is carried out with the ambition of getting the district heating infrastructure a step closer to completing the phase-out of coal. But how to practically study such relations?

4.2 A protocol for studying connected infrastructures

This protocol is both documentation of what I have done to research infrastructure connections taking place in practice but also a simplification (as all writing and list-making is) of my process. As it resides in this space of the dissertation, it guides my approach to study connected infrastructures and is introduced before I go on to document how I how worked with points on complexity in relation to infrastructures. My point with this protocol is that I have tried to stabilise and simplify the two infrastructures in order to locate the spaces of excess that overflow my infrastructural simplifications. Ethnographic protocols imitate strict bureaucratic guidelines while simultaneously challenging them as 'fixed structures provide a space for improvisation and inventiveness' (Ballestero and Winthereik 2022, p. 11). The following protocol also depends on drawing as a form of analysis. Drawing infrastructures, however simplified and quickly we do it, is attending to given weights and scales of the infrastructure itself, by the ethnographer as well by the people, materials and institutions that make it (Douglas-Jones 2021; Corsín Jiménes 2010). The protocol does not produce final publishable products but is an aid for jump-starting the analytical machine. The product of my protocol is this total thesis. When writing the three articles, I decided that the most significant engineered valves between the connected infrastructures of district heating and datacenter in this thesis research are industrial excessive material (article 1), tax regulation (article 2), and heat pumps (article 3). Analysing the connection of infrastructures can be conducted through steps such as the following:

Protocol:

1. Identify two infrastructures in your field. Start with only paying attention to infrastructure 1.
2. Write 200 words that describe the infrastructure as it moves from one location to another. Where is it made to end?
3. Spend 10 minutes drawing the trajectory. Do not make decisions on forms and aesthetics of the drawing before starting. Think rather of this step as a drawing version of "free writing" in which you spontaneously get down on paper what is already on your mind.
4. Write 200 words that describe who make it and who make the ends to it.
5. Reiterate step 2 but through the other identified infrastructure. Try to overcome the fact that your familiarity with this infrastructure is different than infrastructure 1 (this will be the case for all researchers).
6. Reiterate step 3 but through the other identified infrastructure.
7. Reiterate step 4 but through the other identified infrastructure.
8. On a piece of paper, list the valves/ends/meetings/connections between infrastructure 1 and infrastructure 2 without descriptions and assumed hierarchy.
9. Which are the locations in which the infrastructures meet? And which weights and scales are given on both sides of these meetings and ends? Share your analytical reflections, the words written and the drawings with a colleague/friend/stranger/supervisor. If they have used the same protocol, then spend 15 minutes each on presenting your materials, allowing enough time for questions and feedback from your peer.

4.3 Infrastructural complexity

Social anthropologists route connections through persons. They attend to the relations of logic, of cause and effect, of class and category, that people make between things; it also means that they attend to the relations of social life, to the roles and behaviour, through which people connect themselves to one another. And habitually they bring these two domains of knowledge together, as when they talk about the relation between culture and society.

- Marilyn Strathern (1995, p. 11)

Much has happened since Strathern's inaugural lecture in 1995 on anthropological issues of complexity and scale. One of them is the growth of the domain of STS that has normalized interdisciplinary research on simultaneously material and social issues. While many social anthropological points and methods have been discarded over time due to their oppressive colonial and culturally essentializing nature, one of the most significant remains is the method of studying how people make connections.

On the problem of studying complex connections, Fortun's (2021) scholarly project with inspiration from Marcus (1995) intends to re-fashion ethnography 'so that it stays tuned to and responsible to its historic moment.' (p. 19) Fortun's project is to reconceptualize ethnography to stay attuned to increasing climate emergency, toxic pollution and, particularly relevant to the point of this section, the ongoing interlacing of infrastructures. The diagnostic of infrastructures coming to be more interlaced as a critical problem might at first stance seem in opposition to Strathern's famous point on complexity. One of her greatest contributions is the point that the modernised society prescribes time as having progressed to constantly increase the level of complexity in the world in human's everyday experience of life. She rejected this modernist hypothesis – so normalized that many people would agree to it being defining to their personal experience of being alive in the 21st century – with the remark that it is not the *amount* of complexity that changes during time but the *difference* of complexity.

I bring Strathern's point on complexity together with Fortun's diagnostic of contemporary infrastructures because infrastructures have not simply become more interlaced over time as a constant inter-complexing of infrastructures - but because infrastructures have changed over time, and most importantly, because infrastructures have enabled the globalizing efforts of organisations and corporations for example through transport logistics and telecommunication. It is the distance between connected infrastructures that has become different in most instances and not the level of how many infrastructures are connected.

Infrastructures can be empirical objects but also analytical vantage points when studying how they matter to life around them as well as how they are themselves affected by use, extension, production and dismantling (von Schnitzler 2015). This form

of analysis is generative as it is resembled in the extensive literature on infrastructures as it has emerged particularly in the 00's and 10's. It is exactly because infrastructures are relational materials constructed to uphold and transform social life (Winthereik and Wahlberg 2021; Downey and Dumit 1997), that they make for such good bases for analysis. It is also because they are often upheld and maintained in the background of people's everyday lives by specialists and oftentimes through invisible labour, that they make for such interesting deep dives (Star 1999). And it is because they enable insight both into the commodities, substances, and technologies that they are charged with transporting but also access into the groups, companies, institutions, and communities that they exchange materials between (Anand, Gupta and Appel 2018; Harvey, Jensen and Morita 2016; Larkin 2013).

In Odense, this relational ethnographic access is not only the infrastructure at one end and the other but the exchange between two infrastructures as they are at certain locations joined together. The district heating infrastructure is made to bring the municipality (that owns it) into being by ensuring the cheapest possible heat to its residents, while it also exceeds the municipality by being managed, planned and extended by the district heating engineers as well as through interventions by citizens and industries that also have stakes in it (Harvey and Knox 2015). Publicly politicized infrastructures, such as pipelines that transport fossil fuels are disputed not only due to the objects in isolation but how they are interweaved with produced information, already established political life and territorial arrangements (Spice 2018; Barry 2013).

In contrast, district heating infrastructures rarely become disputed in Denmark (so far), as they have generally been supported and upheld as infrastructures for the urban future by authorities, engineering scholars and citizens. The only few instances in recent decades in which district heating has become a site for public debate has been in relation to the burning of garbage as it is the largest proportion of fuels within the infrastructures in the largest cities, such as in Aarhus, Copenhagen, Roskilde and Odense. However, in these debates as they unfold in newspaper opinion pieces without much street protest, it is not the district heating infrastructure itself that is problematized but the lack of incentive to recycle materials when they are burned at large scale as well as the travelled distance of the imported and shipped garbage that is

necessary to keep the energy plants sufficiently fuelled for the areas they cover (Kall, Ford and Schick 2021).

Infrastructures span across a variety of scales and sites. The district heating connects residents, visitors, and workers in Odense with the energy plant and the local politicians. It also connects to the Danish parliament when it is used as an exemplary case of a district heating network connected to a datacenter because it is in fact connected with a continuous flow in between. And when its future is transformed because the Climate Agreement of 2020 articulated a need for more industrial excess heat and district heating projects. With this approach to withholding connected, complex infrastructures in analysis and how to do so, the following chapter introduced analytical implications of the study, thereby moving from which are the material components within research and onto which are the material consequences of the analysed components in the research.

Chapter Five: Analytical implications

The original academic contribution made by STS lies in the analysis of how knowledge is produced through scientific practices (Law 2004), paying close attention to the practices in laboratories, offices, archives, and machine rooms, and the places where the materialization of science in technology is utilized, such as in hospital wards, coding spaces, workshops, farming fields, and nursing homes. The original analytical interests have lived on as an approach to studying what takes place in the spaces one can visit physically or metaphorically; for example, an early study of the laboratory as a system that *produces* materials documented that the central products of a given laboratory are economically very expensive and scientifically specific texts (Latour and Woolgar 1986), that in turn culminate in producing both cultures and natures (Traweek 1985). Much has happened inside and outside the literature since then, and the laboratory does not directly have much to do with this study, but my point with mentioning it here is to show the extent to which the processes of material production are a true STS concern, just as they were to other fields and literatures academically assembled in the past. The same could be said of most natural sciences in the sense of having carved out how materials produce materials or, rather, 'how the world produces itself'. Yet not all scientists would agree with such a description of their field, preferring the phrasing, 'how the world is how it is' (Stengers 2005).

5.1 From vernaculars of production to reproduction

STS is often described as a socio-materially constructivist, but nonetheless pragmatic field, but here my gaze is turned to the study of socio-material production rather than specifically construction, not just in the methodological or onto-epistemological sense, but in a specifically empirical-turned-analytical way. 'Producing energy' is the vernacular the utility workers that engineer district heating use to describe their work. I have observed and participated in their production of energy and can therefore document how they do it. Every year FDH publishes an annual report with an overview of events and economics in which the emphasis on production stands out:

All production facilities are managed and maintained by Fyn District Heating. On top of the production from own facilities, heat production also includes other suppliers. ...

From early 2020, Tietgenbyen facility will also deliver a considerable amount of excess heat from Facebook's new datacenter in Odense (Fyn District Heating annual report 2018; translation by author).

FDH is split into separate organizations with their own, yet co-dependent budgets: FDH energy plant, FDH distribution, and FDH waste-to-energy. The differences between making pipes, transformers, and meters work, and actually producing energy stands out; thus, the distinction between production and delivery is very clear, not just internally but particularly in relation to industries that deliver excess heat. On several occasions I was reminded that industrial excess heat is a form of energy that is not produced by the industries but delivered as a leftover from their industrial production; I go into this distinction in greater ethnographic detail in Article 1 by showing how it constructs the difference between excess and non-excess, Nonetheless, it is worthwhile mentioning here not only how important the process of material production is to the work of the engineers in vernacular terms, but also how production is an exclusive term that helps differentiate processes producing energy from processes circulating materials that can be *used* for producing energy. From the perspective of FDH, the Facebook datacenter, while producing data, circulates server air that can be used to produce district heating.

But what can be learned from the literature on this work of production? First and foremost, that production requires reproduction. In this section I introduce the analytical implications of research findings that assist me in answering my research question. I build on existing conceptual work within STS, anthropology, and feminist theory to show how the concept of 'reproduction' informs my analysis. Then I mobilize two terms, 'reconfiguration' and 'replication', that are sometimes utilized in tandem with studies of reproduction. Here I assemble them as sister terms that provide enough action with 'reproduction' for serious analytical play without stealing the analytical spotlight: consider reconfiguration and replication support acts, if you will.

The decision of mine to write up these analytical implications of reproduction is to take the productionist aspect of reproduction to its mechanical roots to analyse it from a generational perspective: where does production come from and how is it made to

continue? Haraway has suggested avoidance of the concept of 'reproduction' due to the effect of industrial production on planetary crises (Mitman 2019), yet I have chosen to analyse the empirical relations in which the concept is actually still used to make sense of infrastructures that construct economic and societal value. Reproduction is a concept that has been developed, critiqued, and mobilized in new and interesting ways within the realms of feminist scholarship, specifically in relation to technology. In this section I write up a brief history of the concept in a move to take it on a tour to its origins within the study of industrialization: specifically, to examine what research on the decarbonization of energy can learn from the analytical advancement of research on inequality and material, generational power; in other words, how are not just commodities and bodies, but material, industrial power reproduced?

5.2 A mimicry of production

On the analytic significance of Engels' theory of relations between the original development of the 'private property' and 'social inequality', Tsing (2012, p. 145) writes, 'Notions of property used to regulate the reproduction of herds inspired male control of reproduction in human families.' In other words, the reproduction of herds through property regulation produced the regulated reproduction of humans, particularly through male dominance. Tsing mentions how Engels' analysis was picked up by feminist theorists and anthropologists in the 1970s and continues:

> By the mid-1980s, feminist anthropology had turned to the specificity of ethnographic research to learn more about the cultural construction of gender. While this has led to many important insights, it has also left the field of long-duree storytelling to misogynists, including sociobiologists, medical doctors, and s-f writers, most of whom are not well read in history and anthropology. Perhaps it is time for feminists to re-enter the fray. (Tsing 2012, p. 145)

While Tsing's argument about the difference and simultaneous importance both of gender construction and historical and anthropological analysis of the construction of social inequality is a useful takeaway, I find more levels of importance in the statement. Obviously, there are many authors who call themselves feminist or have strategically decided on other terms of identification that have 'entered' or even stayed 'in the fray'. Yet Tsing's statement can be taken as a motivation for scholars with an eye for

production and reproduction to write analytically for broader audiences, specifically, by explicating why their insights are relevant for many sites and people beyond a local or regional focus. Many have found feminist research practice to make most sense as a form of hyper-localization that focuses more on collaboration with interlocutors and issues of situated impact than Tsing's 'long-duree storytelling'. However, her point, as I read it, is one that attempts to ensure that all those who want to participate in analytical projects similar to hers know that such projects are needed.

The above claim – that the reproduction of herds according to notions of property constructed the reproduction of humans by making women property – is not the only formulation. Before feminist scholars of the 1970s such as Eleanor Lealock, Evelyn Reed, Angela Davis, and Lise Vogel re-theorized 'reproduction' – and before it became a tool in STS for the analysis of technologically assisted birth giving, population control, fertility, and 'reproductive biomedicine' in the 1990s – the study of reproduction was more interested in labour than bodies.

Engels' book *The origin of the family, private property, and the state* (1972 [1884]) is considered by many one of the first major works on the processes of reproduction. The theories in the book are largely drawn from anthropologist Lewis H. Morgan's writings on kinship relations and the evolution of family arrangements, based on which Engels wrote about the family as an economic unit essential to the reproduction of the capitalist workforce in the factories (Lealock 1972). Through a somewhat anthropological lens, it built on Marx' writings (1992 [1867]) of political economy and the distinction between what he called 'simple and extended reproduction.' In other words, on how capital circulates: the difference between the continuation of an industrial production process by sustaining it and the accumulation of an industrial production process.

As an inheritor of many theoretical academic drifts, including the critical theory of the Frankfurt School, in the 1930s Walter Benjamin came to reproduction as a concept so sedimented that it could be used to describe how things and processes are remade through the means of industrial production instead of being merely a specific, exclusive concept. His 1935 essay, 'The work of art in the age of mechanical reproduction',

describes the societal shift in practices of and access to art through industrial mechanization, asking how the work of art has changed as it has shifted from mainly being mediated through paintings with the normalization of photography and films. Benjamin's (1969 [1935]) interest in reproduction rests on his interest in urbanization, which was a major societal concern at the time. 'Reproduction', then, is used as a device to study a form of before and after, with mechanization as the watershed. It allowed him to explore the effects of mechanization on important human processes, such as art, and how art was suddenly made a collective matter rather than the exclusive province of the elite. Thus, he was suggesting that it was not reproduction itself that was new but reproduction by the means of mechanics. His argument counters that of bourgeois thinkers of the time who claimed that art in itself had been ruined by the widely distributed access to making and experiencing art by means of photography, films, and the textual press; rather, he shows how, through its mechanical reproduction, art comes to be no longer based on mainly the practice of rituals but the practice of politics.

In the footsteps of Benjamin, reproduction – as a process that materially remakes practices – has been studied meticulously in relation to art and media as a concept that centralizes societally important shifts. He argued that these 'new reproductive means' were a collectivist issue, in the sense that the more something, such as art, can reproduce itself, the more people it can reach who can get something out of it (Franklin 2002). Whereas Benjamin's perspectives on reproduction by technological means stayed away from determinism by not judging the extent to which these new mechanical processes were ultimately liberating or enslaving, reproduction as a shift in societal processes came to hint at the descriptive effects: the extended distribution of access due to the production, not just by new technologies but specifically technologies that could accelerate access.

When reproduction as a concept was picked up again in the 1970s, the feminist scholars who theorized it had become aware that some of the hoped-for emancipatory effects of technologies, still alive in the 1930s, had not materialized. In many places, the industrialist processes responsible for producing these technologies had only become more corporate and beneficial to the few, and many women were still bound to maternity as their primary profession. Take, for example, this analysis from Juliett

Mitchell's book *Woman's Estate* (1971) as it is quoted in Marilyn Strathern's *The Gender of the Gift* (2001 [1981]):

[R]eproduction in our society is often a kind of sad mimicry of production. Work in a capitalist society is an alienation of labour in the making of a social product which is confiscated by capital. But it can still sometimes be a real act of creation. ... Maternity is often a caricature of this. The biological product the child is treated as if it were a solid product. Parenthood becomes a kind of substitute for work, an activity in which the child is seen as an object created by the mother, in the same way as a commodity is created by a worker .... [t]he mother's alienation can be much worse than that of the worker. ... The child as an autonomous person, inevitably threatens the activity which claims to create continually merely as a *possession* of the parent. Possessions are felt as extensions of the self. (original emphasis) (Mitchell 1971, p. 109)

What to do with this sad modus of reproduction: biological human reproduction as a caricature of laborious commodity production? There are fortunately plenty of examples in the literature that deal with the analytical consequences of this.

5.3 To reclaim or to resist reproduction?

Anthropologist Eleanor Leacock wrote the updated introduction for a new edition of Engels' 'family book' published in 1972. In an extended text she commented on the outdated analysis that suggests that women's liberation will come with the overthrowing of capitalism, arguing that overthrowing economic inequalities is only possible with the prioritization of the liberation of women and people of colour; in other words, the causalities for the way to liberation should be reversed. Still, having agreed to write the new introduction, she elaborated on the contemporary relevance (in the 1970s) of the analysis of reproduction read in the light of feminism: 'However, it is crucial to the organization of women for their liberation to understand that it is the monogamous family as an economic unit, at the heart of class society, that is basic to their subjugation' (Leacock 1972, p. 28).

In the wake of the 1960s, in which both economic and monogamistic critiques were aplenty, then Leacock's point, as I read it, was to insist on the combination of this foundation: that the family as an economic unit was the best way for the capitalist state to reproduce its workforce. Thus, the category of 'the family' became more essentialized

and normalized as it became economic than in settings and times in which reproduction of the family, for example, was necessary simply for the ongoing maintenance of a farm. Evelyn Fox Keller (1987) in the following decade elaborated on how evolutionary theory has long reinforced the effects of reproduction – through theories and methods particular to the evolutionist spectrum of biology – by normalizing the idea that reproduction was an individualist activity, therefore a private rather than a collective matter. In contrast, Keller documented how human reproduction was not a process undertaken by the autonomous individual organism, as the evolutionists had suggested, but by the complex cooperation of organisms. In turn, as anthropologist Emily Martin (1987) has argued on the topic on the medical language of reproduction that determines women's lives, what is biologically conceived of as 'reproductive organs' have become 'systems for the production of valuable substances, such as eggs and sperm' (Martin 1991, p. 486).

Keller's and Martin's analyses are among the many impactful scholarly projects that took on the responsibility to revisit biology's theories of reproduction with a feminist lens. From the 1970s onwards came the 'wages for housework movement' on which Silvia Federici founded her research on the subjugation of women to the duties of care work. Studies eventually turned to reproduction as a question of fertility, birth, childbearing, housework, childcare, and the socialization of children, yet mainly with a focus on women's experiences, as suggested by Ginsburg and Rapp (1991). This line of scholarly and activist feminism has had substantial achievements, including the definition and achievement of reproductive rights in a long list of legal settings. By reclaiming reproduction as a means of care in contrast to reproduction as a means of bodily regulation, these studies clarified how the household is a 'space of "consumption" (of capitalist commodities) and of "reproduction" (of the capitalist workforce) rather than as a space of noncapitalist production and consumption' (Gibson-Graham 2006, p. 8). The special space for care work as reproduction has also been inherited and built upon by contemporary 'social reproduction theory', which pays special attention to the relations between the circulation of capital and the maintenance of care work involved in services such as food, housing, public transport, schools, and hospitals (Mezzadri 2022; Bhattachrya 2017).

Marilyn Strathern came to the topic of reproduction through contrasting sexual reproduction with maternity (reproduction of children) and with the social reproduction inherent to the circulation of goods and people (reproduction of society). Queering such analyses in relation to sexuality, gender, and the boundaries between bodies and technologies are clear in the works of 'feminist technoscience'. Sarah Franklin, on her part, has studied new technologies of biomedicine such as in vitro fertilization (IVF) and preimplantation genetic diagnosis (PGD), meanwhile turning against anthropology's former conceptualizations of reproduction. With the latter form of analysis, it became apparent that classical anthropology's obsession with paternity, lineage, and what was in many ways 'reproduction' – without using the word reproduction – assigned it to the 'natural' domain of individual biological facts contrary sociality as a process that occurs after and outside the reoccurrence of biological lineage (Franklin and Ragone 1997). In other words, the meaning of reproduction was so clear, if not mentioned, in early writings within and outside anthropology that it was difficult to interrogate the problems with its usage ethnographically.

For the same reason, assisted reproduction technologies and how they have been governed have resulted in a variety of discriminating practices due to the increased medicalization of childbearing, including policies privileging heteronormativity and citizenship status in insemination and fertility processes (Dahl 2018; Lie and Lykke 2017; Mamo 2007; Bryld and Lykke 2000). New childbearing technologies that allow for certain forms of selection also present the problem of preventing and promoting the birth of certain kinds of babies over others (Adrian 2020; Wahlberg and Gammeltoft 2017). This often hidden but regulating power of reproduction when used as a mechanism is made prominent in Franklin's work on academic sexism with the reminder that reproduction refers to 'the conditions of consciousness that enable the maintenance of existing institutional patterns, habits and structures' (2015, p. 30). According to Franklin, the question is simply not one of what is reproduced and what is not but, rather, redirected, disciplined, policed, weeded out, and swept aside? Michelle Murphy has asked similar questions in relation to reproduction in terms of not only *what* is weeded out but specifically *who* is swept aside. In relation to evolutionary theories that have 'made' the population and regulated which bodies were considered more fit to be citizens of the state, Murphy (2015, 2012) has documented how

reproduction in Enlightenment comparative anatomy was a concept used to define and ensure the conservation of human forms across generations. As Murphy writes, '[r]eproduction, thus, did not merely remake life as more of the same; it generated constellations of variation, more or less adapted, more or less primitive, and more or less valuable. Reproduction became a living difference engine' (2015, p. 288).

As an engine that produced violence against indigenous communities, people of colour, and any other minorities that were characterized as deviating too greatly from the majority, reproduction was a mechanism that 'created the population', in Murphy's words. Later, however, by extending the mainly legal perspective of 'reproductive rights', the concept of 'reproductive justice' was reclaimed and redefined, particularly by minority groups, to redirect the focus of reproduction from childbearing to life conditions. The narrow, although important, scope of legal rights to childbirth, abortion, and contraception in the reproduction concept as it was developed mostly by white feminists of the 1970s and 1980s, had not addressed the violence of generations of 'population making' (Murphy 2015).

5.4 Reproduction beyond bodies

While feminist scholarship works across academic disciplines, similar to and within STS, feminist approaches to studying the power involved in scientific practice and technological development is also a backbone of STS in general (Wajcman 2010). Haraway's major project of capturing the technological zeitgeist of the 1980s, materialized in 'the cyborg manifesto', was to reclaim technological development for the construction of less binary futures. The hopeful descriptions of walls about to break down are evident in Haraway's argument for the coming of the age of cyborg feminism:

> The 'multinational' material organization of the production and reproduction of daily life and the symbolic organization of the production and reproduction of culture and imagination seem equally implicated. The boundary-maintaining images of base and superstructure, public and private, or material and ideal never seemed more feeble. (Haraway 1990, p. 207)

The intense change that came with the dawn of the digital age was certainly a moment in which hopes that resembled the gist of Benjamin's modest optimism on behalf of

distributed media could take root. Haraway's project was to reclaim the digital and bioscientific technologies that were not built for feminism but could, nonetheless, and with the right conditions, provide opportunities for a more just reproduction of both daily life and culture. This would be achieved by countering the naturalized, sexualized conceptualization of reproduction as a process that goes on within the boundaries mentioned: fully public or private, fully material or ideal.

What is cyborg reproduction? Haraway asked, and looked to the material boundaries that were once regarded as containers for everything but had suddenly taken on new meanings, such as human skin. Human reproduction was no longer mainly a sexual issue as new technologies had changed the game of childbearing. Especially important to Haraway is how this analytical conjunction has created a momentum for reproduction as more than procreation, indeed as an opportunity to reclaim reproduction for making multispecies kinship, practicing queer relations, and working against the profit-seeking development engine (Andersen 2020).

As elaborated on with the term 'chrononormativity' coined by Elizabeth Freeman (2010), as well as Alison Kafer's (2013) work on 'crip time', normative frameworks of human productivity build on the common idea that all humans experience time in the same way. These frameworks of universal technocratic time situate some bodies as potentially more productive, and therefore more valuable, than others. Playing with Haraway's (1990 [1985]) question, 'why should our bodies end at our skin?', Murphy (2013) has asked 'why should reproduction end at our bodies?' The question has a role in describing the concept they title 'distributed reproduction'. Their studies explores messiness, complexity, and contradictions. As the examples I have introduced here show, studies on reproduction often come to prioritize a focus on either labour or bodies. If reproduction, not just as process but also as infrastructure, was to be documented, Murphy ponders, it would require insight into how they 'connect bodies and labour, but are not reducible to bodies and labour'. It is not a question of the relations between bodies and labour but of figuring out where and how concepts of 'abundance, growth, and fertility' are detached from the organization of laborious productivity (Bear 2018). According to Bear, Ho, Tsing, and Yanagisako (2015), it is the productivity of reproduction that has accumulated social inequality: for example, in

terms of the selective effects of planetary eco-catastrophes. Is reproduction reclaimable at all or is it a process that always has been and will remain regulated by the productivity of industrialists, including the new generation of digital industrialists?

5.5 Replication, reconfiguration

Answering the question above requires an interest in the boundaries of reproduction. If reproduction means more technologies – or, at least, greater circulation and access, as explicated by Benjamin – then reproduction is akin to replication. Haraway's project famously examined the detachment potential of digitalisation from essentialist biological organicism, but the following statement can also be read with an eye for the difference in the processes: 'Cyborg replication is uncoupled from organic reproduction' (1990 [1985], p. 207). The suggestion that the cyborg age frees humans from reproduction for a horizon of simple replication is captivating. Haraway does not want to reclaim reproduction as a form of nurturing or care work, rather avoiding the reproduction concept entirely because it entails endless productivist accumulation (Mitman 2019). Thinking with 'cyborg replication' also means thinking about all the things that do not need to be changed for survival and subsistence in the age of human-made climate change.

This thesis builds on the presupposition that district heating in Denmark as a welfare infrastructure has thrived and become extended more than in many other sites because they could not supply similar collectivist conditions. The years I have ethnographically and analytically followed Danish district heating, as a certain material, societal, organizational, and legal entity, have made it apparent to me how seriously neglected a publicly collectivist (if preserved as such) these infrastructures are. While the fuels used by the district heating infrastructure need serious replacement to ensure decarbonization, with sufficient careful engineering, planning, and funding it will continue to supply major cities and small towns with cheaper and less carbon-intensive than individual heating with sources such as gas, wood pellets, and oil burners. The 21st century has seen an accumulating interest in how to innovate, change, and fully reorganize energy policies for decarbonization. Indeed, Geels and Turnheim (2022) suggest 'The Great Reconfiguration' of electricity, heat, and mobility systems. Despite requiring new fuels, which is a project in itself, the energy plant and distribution

pipework of district heating in Odense has always been the target of major changes, extensions, and reorganization; it is not an example of one of those systems that needs to become totally different to fit the requirements of its age. It does not need major reconfiguration. Although the sustainability ethos is rich with hopes for reconfiguring interventions, I question how many more infrastructures and technologies used in practice – like district heating – would eventually emit less carbon if not innovated to accumulate. But partly extended where needed for the substitution with other heating sources such as natural gas – in general merely maintained and replicated over time. While the funding, innovation, and production of negative emissions technologies are crucial for societal decarbonization plans to succeed (Buck 2016), new technologies and infrastructural reconfiguration projects do not lead to decarbonization just because they are termed 'sustainable', 'green' or 'circular'.

As Lucy Suchman suggests, hopes for technological reconfigurations are 'based not in inventor heroes or extraordinary new devices, but in mundane, and innovative, practices of collective sociomaterial infrastructure building' (2017, p. 361). Similarly, Barad does not see reconfiguration as large, intentional, human intervention but rather as agency, as 'the ongoing reconfigurings of the world' (2003, p. 818). This version of reconfiguration as replication that continually produces minor changes and maintenance stands in contrast to the major energy planning systems approach of 'the great reconfiguration'. In computing terms – which is also whence Suchman derives the term – reconfiguration does not refer to a process, but to the measure of how much a system is capable of having its parts arranged in a new or relatively new way.

5.6 The work of energy in the age of digital reproduction

Reflecting on the ontology of reproduction in relation to its sister terms of reconfiguration and replication offers the insight that what effects the difference of producing more new things and more of the same things is a question to which the literature has not given an answer. Potentially, this is because such an answer depends on the purposes of measurability for industrial production in contrast to 'letting things be'. Reproductive work is indeed a site that needs studying rather than being enrolled as a theoretical solution to the consequences of industrial production. Like both replication and reconfiguration, reproduction entails continuation; however, whether

the continuation involves accumulation (expansion) or maintenance (subsistence) is a question for situated studies such as this one. Reproduction is a contrast concept: not a thing in itself but the conceptualization of a process that helps delineate temporalities and materialities that produce the continuation of industrial productivism.

This age of digital reproduction in which energy is continuously made to work is the overall topic of this thesis and explored in the articles. Reproduction as a concept sensitizes production processes to asking more questions such as: When is something or someone productive? To whom? According to which measures? What is non-productive work? Non-productive work for decarbonization or for industrialization? Which forms of work are productive according to GDP measures or those of the local economy and not to decarbonization – that is, not productive to survival of humans and multiple other species? Let us take reproduction to the productivists to learn about contemporary productivism and why industries are reproduced and reinvented beyond mechanics into electronics and digital technologies.

After this steep dive into the analytics of reproduction, I have come to the moment in which I can say that my articles demonstrate how the utility working engineers not only produce energy, but also reproduce energy according to contemporary conditions and societal and planetary requirements, such as climate change and shaping climate policies. I state this here because it is not a concluding finding but a simple trait of the relations in this field. In the spirit of Benjamin's (1969 [1935]) form of asking analytical questions: What is the work of energy in the age of digital reproduction?

Chapter Six: Conclusion

This thesis examines ethnographically how energy has come to be produced in connection with the digital economy as well as which effects this emerging connection has on utility work. It has done so with three original research articles (two in review and one submitted), by a short reflective coda and with the chapters of the thesis. Following the chapter on the analytical implications in relation to processes of reproduction, this chapter concludes the thesis by putting forward the scientific implications in relation to STS, social science research on energy decarbonisation, and the practical complications of energy production in the age of Big Tech.

6.1 Vernaculars of production and ethnography of connected infrastructures

As many energy scholars have argued before, energetic power is always symbolic and material power, and contemporary societal power similarly requires energetic power. This thesis takes the findings on power further. Because it shows two different but connected forms of power: the one that is reproduced for the furthering of the digital, centralised economy and the other one that is the outcome of producing shared energy. The sites of production and reproduction are different than the sites of scientific knowledge construction, digital replication and energy systems reconfiguration. Practices and politics of power play a role in all these sites yet take a certain form in the context of energy production and digital reproduction. The power of sharing energy (which district heating shows), and the power of caring for sharing energy (which the utility work of district heating shows), is incremental – yet exposed to economic interruptions – for critical infrastructure maintenance within planetary, climatic boundaries. The reproduction of the digital economy through the sharing of energy however shows that Big Tech's infrastructures have many openings, endings, valves, knots and transmission points that can be accessed not only by major technology companies but also by those with enough ethnographic interest to do so.

Despite the fact that the thesis has elaborated on power from an empirical (not theoretical) perspective, this finding on differences in power comes about through the study on the vernaculars of production – an outcome from the ethnography of

connected infrastructures that allows for insights into deliberate infrastructural connections and de-connections in practice. Building on the three conceptual contributions to STS of industrial excess, layers of reciprocity, and the collisions of scientific laws, the implications for further research have more of a methodological character than theoretical. The thesis argues for the continuation of studying ontological politics through and by positioning first empirics, practices, and local concerns and by contrasting it with documented knowledge in areas that might only seem connected not at first but perhaps at second or third sight. Thus, it suggests not specifically further studies into reproduction as a kind of special area of research of interest to decarbonisation but the unravelling of what can be learned from entities that are connected yet in contemporary societies become unconnected due to various forms of organisation of what belongs together and what does not – such as with the processes of energy production and industrial reproduction that I have mobilised to position industrial production as a special area of interest to social studies on how to decarbonise energy.

6.2 Industrial production, welfare infrastructures and utility work

The electricity currents of the Nordic grid and the infrastructures on which they run however provide a contrast to the organisational dimensions of publicly owned district heating. The history of local heat infrastructures in Denmark shows that these only come to survive and extend if intervened into through economic regulation and with local responsibilities for continuously planning for its maintenance and development. The no-profit principle of district heating in Denmark ensures cheap, accessible heat, and the history of the politics around such regulation shows the extent to which district heating is an infrastructure that only thrives and enables decarbonisation of heating with the policy implementation and maintenance that characterises the welfare state. The argument of district heating as a welfare infrastructure that needs sufficient amounts of care work to work at all positions utility work as a special place of interest for ethnographic studies of how decarbonisation is (successfully) done in practice.

The work of connecting the two infrastructures shows that while Facebook continuously uses the project of server heat for district heating to showcase sustainability initiatives, the achievement of transforming air from datacenter servers

to public heat is solely one of the utility workers and their machines. Additionally, new financial energy market mechanisms enable Facebook to proclaim supplying the datacenter with 100% renewable energy while it is connected to the same electric currents as any other electricity consumer in Denmark. These mechanisms, corporate power purchase agreements, gives the tech industry the opportunity to finance new energy construction projects while going under the radar for hyperscale energy consumption – and it enables major corporations to freeze their own energy consumption prices (therefore also the costs of industrial production) at times when electricity prices are low. The digital economy's financing scheme for renewable energy is with formal governance facilitation in practice rolled out as a gift (Facebook calls it a donation) very much in line with the business model of the platform operations. Yet the added energy only is to match the consumed amount of energy, and land areas prospected for renewable energy construction are – with a socio-economic term - a sparse resource (see figure 2).

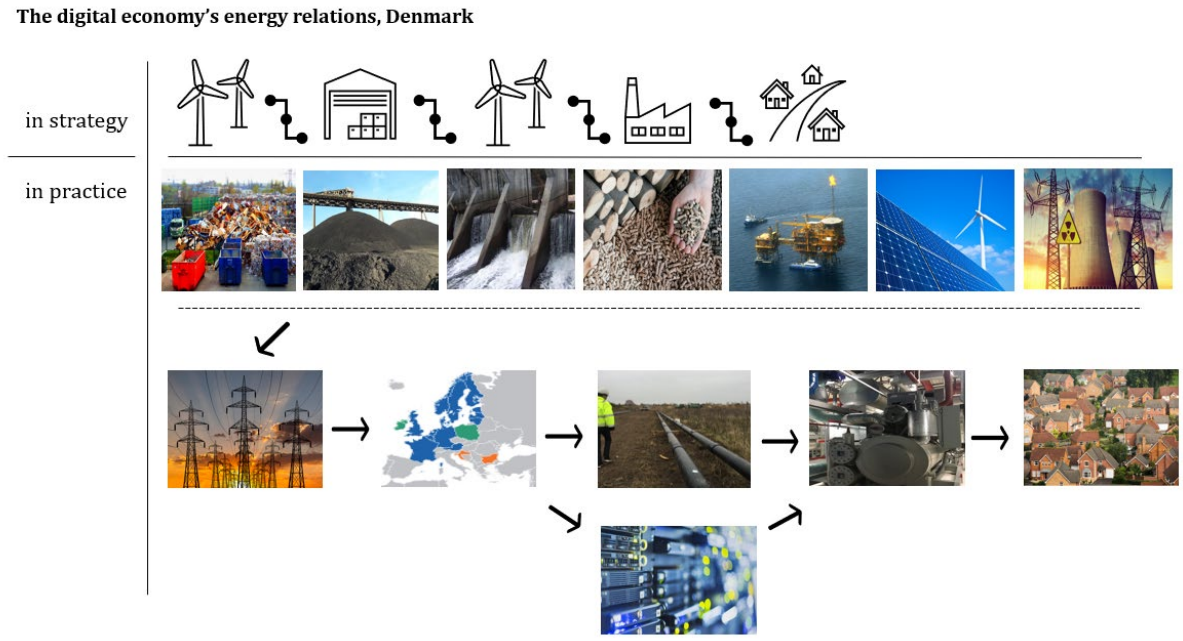

Figure 2. The digital economy's energy relations in the case of Denmark. The figure provides an example of the contrast between Facebook's strategic descriptions on the energy relations of the datacenter with how the engineers' have described the energy system in practice. Facebook's descriptions of their energy production and consumption and the specific materials referred to are elaborated on in articles 1 and 2.

The thesis positions spaces of industrial production and welfare infrastructures maintained and retrofitted by utility workers to be of critical interest to social studies of energy. In that sense, welfare is in the context of the political environment of Denmark not only goods, services, or social rights but an environment of sharing both the maintenance and benefits of infrastructures. The 'shared' quality of the district heating infrastructure is also what makes it so easy to intervene into, change and extend both with regulation but also with the business strategy of industrial convergence. Conceptualisations of the distinction between public and private actors have with the study shown to be inadequate for grasping the power at play in efforts to decarbonise energy and require to be reconceptualised in the realm of new distinctions between shared and industrial infrastructures.

6.3 Big Tech's practical complications for energy production

Some infrastructures are already made and enabled to share energy, while other infrastructures are constructed to stockpile it. The infrastructures that share heat and those that share electricity are in absurdly different conditions. Additionally, storing data for the material benefit of the few enclosures the available amount of energy in current energy infrastructures that are built for the benefit of the public, which creates a major problem to transparently and fairly decarbonise the energy infrastructures that currently exist. The electricity system as it is organised allows for the stockpiling of not just data but also potential energy that works against the sharing of energy that decarbonisation of existing energy infrastructures requires.

Directing material excess into public infrastructures is becoming a business tool of data industries in making the details on material processes of production and consumption inaccessible to both utility workers, politicians, users, and the public that are daily enrolled in the digital economy. Platforms are however not the only material structure that the data industry has remade social life through. While users and technology companies of the digital economy are connected in the reciprocal relation of exchanging service access and data, companies and politicians of the welfare state exchange (unfulfilled) promises of economic rewards for access to land, energy and autonomy.

The absence of sector-specific regulation on data industries in relation to land and

energy is reflected in other current welfare political approaches to decarbonisation of energy. The engineering practice of energy conservation for decarbonisation of energy production is experiencing an impact event as new climate policy install the practice of market competition into the work of developing and extending energy systems. The status of district heating as a monopoly yet contrasts the monopoly of major technology companies such as Facebook. While policy is installed to cultivate heating without profit, accessible to all in urban areas and as cheap as possible, the monopoly status of Big Tech is the only major aspect of the digital economy that has been acted upon in relation to governance intervention. The digital economy is not just any economy, and major, digital companies are not just any companies as they arrive with new business models that have transformed social interactions, and as this thesis shows, also energy interactions. That requires both dealing with the emission effects of the tech industry as not just any industry as it requires more specific intervention into the emission effects of industries in general.

This thesis suggests from a practical perspective that workers of the utility sector and policy makers must turn to this problem through similar attention to 'industrial production' as the interventions and regulations into processes of 'energy production'. If 'energy production' can be a measurable entity within utilities that is governed based on its measurement – how much energy was produced today/this year and with which fuels? with which and how many emissions? – why is industrial production not? And could it become so? This thesis shows that successful utility work – such as with district heating – has required deliberate regulation and local, political responsibility as well as resources and funding to keep on the track of energy conservation for the target of energy decarbonisation – yet economic competition hinders and interrupts this work. The major required intervention for the decarbonisation of energy is to (by minimum) politically approach industrial production through the same means of measurement, public responsibility, increased public transparency and limitations to material consumption and production as currently applied to the utility work of energy production.

The power to share energy between public and private actors is enabled by an existing infrastructure around district heating as well as ongoing non-profitable utility work.

Ethnographic utility studies as exemplified with the thesis helps us better understand how politics in the age of the digital economy is incremental and exposed to economic interruptions. The maintenance of critical infrastructure within planetary boundaries therefore hinges on the extension of the shared, local ownership and responsibility forms of district heating onto other infrastructures of energy and beyond as well as practical intervention into the proportions of industrial production.

Article 1

Servers, currents, and utility workers: When industrial excess became a tool, not a feature, never a bug

Caroline Anna Salling
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in review, *Engaging Science, Technology, and Society*

Abstract

Excess differs from to other material processes of late industrialism, such as overflows and surpluses, in that it does not drift out of production facilities and consumption transactions into toxified groundwaters and shareholders' bank accounts. On the contrary, excess is instrumental to, rather than the explanation for, industrial technological growth. For decades, public utility workers in the city of Odense, Denmark, have ensured the absorption of what they call local industrial excess into the local heating system. By the infrastructuring of industrial excess from a datacentre, Facebook positions the energy production of utilities as equally systematically generative of environmental degradation as the impacts of industrial consumption of materials and production of commodities such as data. Thus, we show how the industrial operations of major corporations whose primary concern is financial growth - rather than fulfilling the material needs of local communities - must be analytically positioned as more industrial than public utility maintenance. Energy production and industrial production are neatly folded together on circularity principles but our analysis prompts engagement with the differences in processes of production and consumption by utilities and industries. The excess heat delivery for district heating does not minimize data industrialism's carbon emissions from electricity consumption, and funnelling industrial excess is an energy utility work tool but it is also becoming a tech industry tool. Yet it is important to observe how local utility and public workers

intervene into industrial growth activities, often in mundane contexts such as when heating engineers diagram the boundaries, scales of and admissions to excess.

Introduction

Many corporations are skilled in hiding industrial materials behind factory walls, and Facebook's datacentres are no exception. Hot air from data servers is labelled as waste on the fabricated outside but inside the factory it is incremental to Facebook's deceptive sustainability strategy. Furthermore, while social media data generated by platform interactions is positioned mostly as random, it is never deleted; rather, it is always backed-up and stored in major electricity-hungry server rooms, solely for the furthering of personalized, centralized, digital commercial advertising.

Ethnographic encounters with industrialism, and particularly what Fortun (2012, 2014) calls "late industrialism", promote analyses that pay attention to the toxicity of deteriorating industrial infrastructures in addition to, importantly, their catastrophic environmental impacts. Anti-colonial and feminist activists as well as environmental and discard studies scholars have pushed back against industries that treat the toxicity of chemical infrastructures as mere externalities in order to show that chemical damage is characteristic of industrial production rather than a rare accident to be fixed with single filters to the pipes and chimneys of infrastructures (Liboiron and Lepawsky 2022; CLEAR 2021; Choy 2020; Ahmann and Kenner 2020; Boudia et al. 2018; Murphy 2017; Ofrias 2017; Murphy 2013; Alexander and Reno 2012). Such scholarly engagements with industrial materials position processes of toxifying, leaking, wasting, polluting, and recycling as characteristics of industrial production and consumption rather than merely the effects of industrialism. Infrastructures are increasingly interlaced and knotted together as they age, with new infrastructures generally being expected to solve the problems of older ones (Fortun 2021). And this, we want to emphasize, does not only apply to industries that produce commodities but also to utility infrastructures. On this point, the analytic take on infrastructures and industrialism is not clear in the literature. When and where is industrialism? In this paper our focus on production and consumption takes us to the data industrialism of Facebook through energy systems. Our point is that the industrial operations of major

corporations whose primary concern is financial growth (rather than fulfilling the material needs of local communities) must be analytically positioned as more industrial than public utility maintenance. Utilities such as electricity plants and district heating infrastructures carry concentrated industrial continuation, whereas factories, mines, financial HQs, distribution systems, and sales offices are distributed components of the industrial turbine that sustains itself through 'big business environmentalism' (Goldstein 2018).

This study is deliberately not conducted from within the Facebook datacentre or HQ, but through the work of dealing with the industrial excess from data industrialism from the proximal space of the utility, next to the fenced walls of the Facebook datacentre: not merely accepting or censuring it but by making it analytically productive. Yet, arguably, data industrialism in Odense rests on a certain aspect of local difference in relation to inequality. The cases of Facebook and other data industries elsewhere have demonstrated controversial and harmful extractive impacts on local communities and environments as corporate hyperscale datacentre operations come with few local jobs, enormous concentrated profit, landscape capture and enormous amounts of water extraction (Greene 2022; Munn 2021; Bresnihan and Brodie 2020; Hogan 2018). Furthermore, despite considerable local public involvement in enabling data industrialism to arrive, and expectations of national and local economic benefits (Pan 2022; Barr et al. 2022; Maguire and Winthereik 2020; Burrel 2020; Vonderau 2019), these industries can abandon and downscale facilities so suddenly that ruination often surprises locals who were promised jobs and increased revenue for local business (Velkova forthcoming).

In December 2022, hundreds of construction workers at the Odense datacentre were laid off without severance due to the corporation's decision to develop more AI datacentres for 'the metaverse', instead of the more traditional backup storage versions. However, this event is the first in which Odense's locals have been severely disappointed. This, and the position of the city as a generally affluent, urban location in the Global North, has enabled our insights onto industrial excess that has come about through local and mundane engineering practices and without social uprisings against the datacentre's operations. The corporation's extractive consumption of energy has

many more effects at the scale of carbon emissions than the extent to which it damages this particular local community and environment.

To demonstrate how excess materially enables industrialism by staying within the infrastructured process of production and consumption, we first contextualize our ethnographic interlocutors of the utility: heating engineers tasked with utilizing the hot air from the servers of a new, local Facebook datacentre for the site of a publicly owned heating system in Odense, Denmark. Making the server air useful is one step in the engineers' decarbonization plan, which mainly consists of replacing coal with electricity-dependent technologies that increasingly rely on wind energy. While the engineers are passionate about phasing out fossil fuels as fast as possible, their work is also enabled by nation-wide energy and climate policies whose aim is the convergence of industry, including Big Tech corporations, with energy utilities as a strategy for more efficient fuel use.

By applying the literature on what we refer to as data industrialism, we then introduce our analytical framework for studying industrial excess before we move into how we engage with excess through the engineers' own conceptualizations in their work practices. The Danish term, *overskud*, refers to the material that is left over from one process and added to another, and we show that, in practice, excess does not just accumulate randomly but is purposefully orchestrated in generating industrial value. This type of scenario makes sense to industries in Denmark given the country's longstanding tradition of funnelling local *industrial excess heat*[6] (the vernacular term) back into energy systems. It is here that a focus on engineers becomes important as we travel with them through their various meetings, discussions, and dilemmas in the course of carrying out the work of incorporating excess from the Facebook datacentre into the utility of the Odense heating system.

In the analytical sections we move through the ethnographic sites of a monthly meeting of the engineers where excess was diagrammed as material between production and consumption, a walk-through of the fossil fuel phase-out plan, and work going on in the new heating building – next to the Facebook datacentre – which hosts both heat pumps

[6] In Danish, *industriel overskudsvarme*.

and visitors. To make salient how industrial excess binds together infrastructural chains of production and consumption, we employ three vignettes on *boundaries* (what belongs inside and outside), *scales* (what is measured by various means), and *admissions* (who gets to participate in the making) as figurative components of excess.

Industrial energy consumption accounts for the majority of carbon emissions, as in 2015 industries consumed 54.8% of the global energy produced (Huber 2022). In 2022, datacentres in Denmark consumed more than 10% of all electricity produced. Based on information on current datacentre projects, the Danish Energy Agency, a government institution, has estimated that, by 2050, datacentres alone will account for more than 50% of the total Danish electricity consumption.[7] Climate change will thus be escalated in the interests of continued, concentrated, industrial profit, although the major, unambitious policy initiative to counter carbon emissions is incentivizing the average citizen to decrease their daily energy consumption. For that reason, it is crucial that Science and Technology Studies (STS) and colleagues attend to how transnational, hyper-capitalist tech industries situate themselves as local businesses that make their extractive activities invisible to the fenced-off outside, but equally to how local people intervene into and make sense of industrial growth activities, often in mundane contexts such as when utility workers diagram the boundaries, scales, and admissions to excess and thereby makes it accessible to study the inside of industrialism.

The site and the interlocutors: A utility that absorbs industrial excess

"We have discussed several options for replacing coal. And the excess heat from Facebook's servers has been part of all the scenarios," Niels says, while seated in a meeting room next to the energy plant to present a slideshow documenting the decisions of the coal phase-out process. He works for the public, municipality-owned district heating utility, Fyn District Heating (FDH)[8] in the city of Odense, central Denmark, and he is one of a large group of engineers that for five years has been

[7] Data combined from two recent reports on the Danish future energy system. 14500 GWh datacentre electricity consumption out of a total Danish electricity consumption at 26000 GWh in 2050 (Danish Energy Agency 2022a; 2022b).
[8] In Danish, *Fjernvarme Fyn*.

responsible for sketching out a plan for ending the burning of coal as a source of heating for the 90,000 buildings serviced by the city's heating infrastructure. Almost every one of the 200,000 people that live in the city is serviced by the system, including those who travel here for daily activities, although October 1 to April 30 is the official season when boilers, stoves, heat pumps, and large collective heating systems, such as district heating, come particularly alive as they warm up air inside the buildings in which lives are lived.

Within the same municipality, Facebook's hyperscale datacentre back-up stores the data of many of its users. Opened in 2019, it is currently the only Facebook datacentre in the world that is connected to a local heating infrastructure; indeed, few other tech corporations have experimented with similar projects of incorporating datacentres into thermal urban infrastructure (Velkova 2021, 2016). In the years leading up to the opening of the datacentre, the heating engineers were busy figuring out how to use the heat from the servers for their heating infrastructure. "Invest in Denmark", a unit within the Danish Ministry of Foreign Affairs, first matched municipalities with Big Tech corporations planning to build European datacentres and then the heating engineers at FDH were tasked fitting this heat into their decarbonization plan. As Niels' comment exemplifies, the server heat was part of all decarbonization scenarios, and he remains clear on the point that using the server heat was not a choice but rather a project they were assigned.

The first author met Niels while doing fieldwork with the heating engineers at FDH. The ethnography was conducted over two months (October and November 2020) when the first author was accepted as an intern and researcher in FDH. Fieldwork consisted of attending meetings, learning from employees as they made their calculations and wrote reports, joining visits to various FDH sites in the city, conducting interviews, and having informal chats over lunch tables. An additional moment of ethnographic serendipity on which the paper builds – receiving an old book with descriptions of the history of excess heat – sparked the organization of a workshop with the engineers for their monthly staff meeting, which provided a space to discuss the historical uses of excess heat and compare them to current practices. It proved mutually interesting and strengthened the first author's relations with the engineers as she was told she had provided some appreciated analytical inspiration for their future strategy-making.

The energy plant in Odense (FDH) was built at the beginning of the 1900s, initially to produce electricity for the city and its surrounding rural areas. District heating infrastructures were slowly built and extended in cities until the mid-1900s. As with other places in Europe, the oil crisis of the 1970s pushed the Danish energy sector to re-think its reliance on foreign energy imports. One practical response was to expand district heating infrastructure by extending networks in urban areas. In more recent years the renewed focus on district heating has been given a particular climate inflection. District heating has, as such, become a central pillar within transition studies and policy.

Image 1. One of the older sections of the energy plant in Odense.

For decades, larger cities have also been using a broad mix of fuels: gas, oil, coal, biomass, and so on, as well as industrial excess heat, the excess from electricity-intensive processes in the production of, for example, cement, butter cookies, potato

chips, metalware, agricultural fertilisers, and fodder. The processing and storing of data (the data production industry), has now been added to this list with the addition of Facebook.

Image 2. The last piles of coal to be used for district heating in Odense before it is phased out as fuel.

In 2015, the FDH engineers began planning the shift towards an energy mix without coal. After considering the potential of replacing it with hot air from Facebook's servers, FDH formulated plans calling for coal to be phased out by 2022 through the integration of more electricity and more industrial excess heat. Yet the technically fairly simple process of installing pumps to use the server air turned out to require a lot of work to make the industrial excess valuable not for Facebook – so it could incorporate the engineers' success into claimed business strategy successes – but for the utility.

Industrial excess between industries and utilities

What counts as excess? And how does one find out who makes and uses it? While the following analysis demonstrates how industrial excess binds data production and data consumption relations together through energy production and energy consumption, here we first clarify our understanding of these relations, as they are made through

sustainability governance mechanisms that treat industries and utilities without differentiation as equal makers of industrialism.

Excess has been studied as both an economic and material condition of the purifying, binary-making consumption society whose most powerful human enclaves try to get rid of chaotic, collective, creative energy (Taylor 2018; Yusoff 2009; Moore 2009; Edensor 2005; Grosz 2001). Bataille's writings ([1949] 1991; 1985), and those that have been influenced by his work, have marked a cornerstone in the social analysis of human-made normalizations of what is enough and too much. However, excess is much more materially specific than symbolized in the instances in which it is lightly thrown around to diagnose material conditions: data excess, carbon excess, toxic excess, excess garbage, and so on. How excess as a term in such contexts could easily be substituted with *surplus* or *overflow* signifies the point we are getting at. Excess is not a condition or a symbol of that condition but a material form that is fundamental to the infrastructuring of industrialism. It is a not a 'culture' to be fixed by restraining one's impulse to watch Netflix (Monserrate 2022). Excess is part of the factory process and, as we will show, can be accessed through methodological and analytical capture that pays attention to the space between the industrial stages of production and consumption; it is a vent in the infrastructure we can analytically utilize to inspect the inner wheel of the contemporary industrial machine.

The *2021 Meta Sustainability Report* states: "We see circularity as key for the essential evolution from a linear system that is extractive, polluting and finite to a circular one that is sustainable. We also see it as our responsibility to use our products, family of apps and knowledge to catalyze circularity in our industry and beyond."[9] Circularity is also the keyword for Facebook's sustainability governance. Sustainable value chains, net zero and circular economies are figurative but powerful replacements for linear material resource management (Buck et al 2023; Sutcliffe 2022; Buck 2021; Carton et al 2020). In the former, all materials and toxins appear to be reabsorbed by the same system which discarded them rather than linearly extracted and disposed of. Both circular and linear material management are figurations of the relations between modes of production and consumption (Corvellec, Stowell, and Johansson 2022), and most

[9] https://sustainability.fb.com/2021-sustainability-report/

businesses have quickly jumped on the bandwagon of using the concepts to demonstrate which materials, such as cables and batteries, they are attempting to recycle. Number 12 of the UN Sustainable Development Goals (SDGs) targeting "responsible production and consumption" also aims to promote material management to shape "a new circular economy."[10] This political dependence on ideas around the circular economy positions the production and consumption relations of energy and of commodities on an equal footing. In other words, energy utilities and industries appear as similar actors in the making of an industrialism that needs to ecologically modernize their co-dependence (Daniel 2022; Zhang 2020).

The linked keywords of the datafied energy system are 'supply' and 'demand', which arrived as specifications of the production and consumption duo. However, in energy management these two pairs are often used interchangeably. Both came to the world of energy engineering through the industrial economic balancing logic of manufacturing more products as soon as assumptions of their eventual consumption seem likely to materialize (Mitchell 2010). Since the 2000s, social studies of energy have proliferated, with results for the environmental impacts of – and innovative solutions to limiting – production and consumption by the agents of nation-states and local citizens. 'Practice theory' has proposed sustainable transition as a problem to be tackled through answering how to energy use energy more efficiently by studying habits, carbon footprints, prosumer roles, and comforts in the middle-class home. We invite the reader to imagine the outcome if such scholarly enthusiasm for decarbonization through production-consumption relations were applied in an equal manner to the energy and environmental effects of industries as central agents rather than households.

Important to note here is the difference between utilities as industrial or, as we argue, utilities that also depend on industries. For example, the district heating infrastructure consumes fuels that are produced through extractivism such as mining, farming, foresting, and so on. The production-consumption relations are nearly endless if one wants them to be. And the concept of 'energy efficiency' has only become increasingly narrow as its implementation in policy has intensified, such as in EU buildings and energy regulation (Dunlop 2022). But the power generation of utilities could in many

[10] https://www.un.org/sustainabledevelopment/sustainable-consumption-production/

places be downscaled if industries did not consume such a wealth of energy in the production of commodities such as data. Our point is that excess as a figure enables the chain on which industries depend. The modernist development project promises both endless infrastructure construction and infrastructure retrofitting (Hetherington 2019; Anand, Gupta, and Appel 2018; Howe et al. 2016), but that problem is not the same in regard to issues of industrial production or equal for all welfare-providing systems that produce without profit. Privatization and outsourcing of energy generation obviously benefits these industries as the material effects of utilities in analysis, activism, and policy are juxtaposed with the effects of industrial operation. Utility provision could come to appear just as corporate as tech corporations. Such benefits are the main reason for a more nuanced distinction between the operations and effects of utilities and industries, including the connecting object of industrial excess, which is not toxic in its own materiality but (it's luke-warm air), however, can have toxic effects when utilized.

The more major industries operate through transnational distribution, the less reasonable it is to consider them as representatives of citizens or as one out of several organized categories that contribute to the socio-economic preservation of nation-states. After all, no major tech corporations are known for their effective environmentalism, for living up to job-creation promises (with decent working conditions) or ensuring welfare effects through considerable tax provisions. Data industrialism rather creates the machine-heavy infrastructure that enables market exchanges through software innovation, entrepreneurship and 'the data-driven knowledge society'. Compared to the historical mega industries, however, the tech industries more globally dispersed industrial circulation infrastructures have made it difficult for researchers to access the corporate industrial machine (Hogan, Edwards, and Cooper 2022; Neilson and Notley 2019).

Through such studies on the "datacentre industrial complex" (Hogan 2021), we already know that the development of data machine infrastructure often extends historical struggles of justice and adds new dimensions, exemplified by indigenous communities experiencing familiar colonial territorial struggles that emanate from datacentre and data collecting observatory constructions because rurality and colder climates are chosen as fitting conditions (Au 2022; Leheudé 2022; Childs 2021). Data industrialism

is the rusty and clunky, hyper-consuming backside to smart, digital urbanization (Ensmenger 2021; Mullaney 2021; Brodie 2021; Johnson 2019; Levanda and Mahmoudi 2019).

The analysis of new machines as they are developed for industrial, scientific, and societal purposes has always been the core focus of STS literature whose general ambition has been to study how public, private, common, and corporate processes are interrelated rather than separate (Jasanoff 2004; Haraway 1997). In the context of this paper, however, we insist on following the industrial as a contrast to processes of utility and public ownership. First, because this distinction is important to the work of our engineer interlocutors (we will show why in the next section); second, we argue that industrial excess is a productive lens for untangling some of the tools of the data-producing tech corporations that have begun the process of rapidly reshaping much of the social life of the 21st century (Zuboff 2022; Poon 2016); and third, many tech business leaders and their political allies of welfare societies are busy constructing a very optimistic narrative of the fourth industrial revolution (the data-driven, interconnected, and smart society) (Schiølin 2020). Building this industrial revolution imaginary depends on increasing energy-consuming machine instalment and interconnection that must be challenged by studying the relations and contrasts of industrialism rather than seeing them as mere epochs and interrelated systems.

'Who benefits'[11] from this specific infrastructural arrangement of data and energy connections is not a million-dollar question. To get closer to accessing *how* data industries benefit from the work of utilities, we employ the organizing terms of boundaries, scales, and admissions through the following three vignettes to understand how industrial excess connects processes of production and consumption.

Boundaries, and the difference between thermodynamics and circularity

The ways that excess figures in the industrial processes of Facebook and the generation processes of FDH are far from similar. Boundaries between organizational entities, such

[11] The foundational question in infrastructure studies remains who benefits/cui bono, as reflected in the impact of Star's (1995) seminal probe.

as Facebook and FDH, are almost never set but mouldable and negotiable (Star 2010). The historical use of excess for district heating in contrast with Facebook's contemporary server air shows the difference.

The engineers tasked with calculating the phase-out of coal meet once a month to give updates on various sub-projects. A couple of days before such a meeting, one of the engineers mentioned a book written by a local journalist in 1999 commemorating the energy plant's 50-year-anniversary, although he had not yet found the time to read it. Another of the engineers eagerly commented that perhaps it would be helpful to talk about the history of the infrastructure when planning its future.

Indulging in examination of infrastructural history is a rare luxury for these harried engineers but talking about the book enabled a conversation about this history. One of the book's first sentences describes early district heating production as dependent on an excess from electricity production at the large energy plant in Odense in the following way:

> The hot steam was taken out of the turbine before it was fully cooled down. The steam was then transferred to the district heating part of the energy plant where it was used to heat up water that runs in circuits within the pipes. This way of producing district heating meant that the steam had to be transferred out of the turbine before full electrical power had been reached. (Dyrbye and Thomsen 1999, p. 89)

"That's basically how it works, even today," one of the engineers commented. Implied by the word "basically" is a major "but" to the description: originally excess was kept within the loop of energy production, whereas today, excess is also industrial excess that connects the material production and consumption relations of industries and utilities. Inspired by the book's descriptions, we decided to get together and discuss these issues in a more workshop-like space. Here, the focus became the history of excess heat used for district heating.

Niels, the most senior of the engineers, prepped the group with a story set in Denmark before the rise of large energy plants and the central heating of buildings. Then, it was popular in many places to build stables underneath homes, so body warmth from

domesticated animals could also function as a heat form. Drawing a house on top of a stable with lines symbolising heat moving upwards, he emphasized that household animals were primarily kept for milk and food. Their body heat, used to warm the home, was a secondary way to utilize the animals and thereby could be seen as a form of excess heat. Niels' example points to how infrastructures for heat were already present before the rise of 'industries', but the heat that would eventually come to be funnelled in between infrastructures, such as in between the utility and the industrial factory only came about with the construction of 'industrial excess' as a material that could be transferred. As the excerpt from the book makes clear, energy plants in the early 1900s initially began to produce district heating as a supplement to electricity production. That is, district heating came about as a side project of the largest electricity plants. The homes, public institutions, and factories of the largest cities were heated by hot water running along newly dug down pipes to and from the energy plant and buildings.

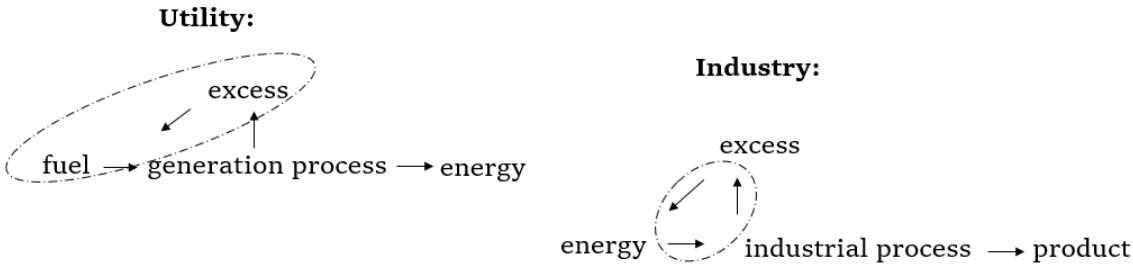
The group went on to draw a diagram of excess heat, describing it through the relations between an *industrial process* and the component *fuel*, *product*, and *unavoidable excess*. One of them drew a square in the middle of a piece of paper within which he wrote "industrial process". On the left side of the square the word "fuel" indicated an input into the industrial process, while on the right-hand side of the square the word "product" indicated an output. Upwards, an arrow pointed towards "unavoidable excess". This is a model for all excess heat from all kinds of industries, he stated. Today, electricity turbines are so efficient that this kind of excess heat is minimal in comparison to how much industrial excess heat is used. Although the types of processes, the fuels, the products, and the forms of excess have all changed over time, they argued, the process that the diagram describes remains the same.

The boundaries to the industrial process, and its excess, to be dealt with by utilities, are drawn as follows. At the centre of the diagram is the production process, surrounded by three input/output relations: *fuels*, such as electricity, purchased to run industrial machines, in this case Facebook's datacentre; *products* that data commodities used for advertising and sold to targeted consumers; and excess heat, consumed by FDH to produce district heating.

The excess of a process can be minimized through energy efficiency measures, one participant added, but it will always be there in some form, since energy cannot just

disappear, according to the thermodynamic constant transformation of energy. What this means, he stressed, is that there will always be an excess from processes that consume energy, with the result that excess heat will always be available in one form or another. It is a thermodynamic obligation to use the locally discarded heat from servers. As Daggett (2019) has shown, wasting energy has been the ultimate sin of energy engineering since the birth of thermodynamics. Danish politicians' agreements with Facebook on the datacentre ensured the engineers *had to* make the data industrial excess useful, but the thermodynamic obligation made them *want to*, as they had been schooled in thermodynamics before arriving at the utility. In other words, it has never really been an option not to use available industrial heat. The engineers' thermodynamic obligation to use industrial excess as a form of fuel is in stark contrast

1. Boundaries of production-consumption



to Facebook's work to isolate the exemplary circularity figure from the material management of their industrial operations (see Figure 1).

At the end of the meeting Niels added that while industrial processes have changed, the way that environmental impacts are handled has also changed. A colleague quickly chimed in that the industries who provide excess heat will always focus on the products on which they are financially dependent. While these industries might be more informed about their emissions than decades ago, economic priorities always trump ecological concerns, he says. Although these relations are connected infrastructurally, the engineered boundaries between the industrial process and energy processes work

to make excess *excessive enough*. It is excessive enough when it is material that would not be used if not consumed by the district heating.

Beyond excess, both logistics and supply chains also connect processes of production with processes of consumption (Rossiter 2016; Cowen 2014) and supply chains (Hockenberry 2019; Tsing 2009); datacentres as industrial halls of data production can be seen as such connecters (Brodie 2020). But these are infrastructural processes that industries themselves develop and carve out. As Diagram 1 exemplifies, however, excess works as a connecter between the processes that are not schematized by industries themselves but rather enabled as the missing piece between industrial production and energy consumption that makes the relations between them perform circularity adequately.

Scales, and the difference between currents and finances

The tech industry and their approach to 'scalability thinking' have expanded centralized business operations by outcompeting and absorbing small, new firms and by delivering information technologies for services of public interest (Pfotenhauerer al. 2022; Balzam and Yuran 2022). Facebook's abilities to scale the overall business itself is reflected in how scales of the excess in production-consumption relations in Odense are managed in order to fulfil the claims of its sustainability strategy through the material of finances rather than through energy currents. It is not only scaling up sustainability initiatives that works but also deliberately only scaling up some material relations in their operations, thereby creating scales of difference between the flow of energy and the flow of energy finance. Niels' engagements with the electrification plan of FDH shows how.

Large trucks that deliver garbage to FDH's incineration area rumbled by outside as Niels talked about the end of the coal era in Odense. He pointed to the storage area which was recently filled with coal for the last time as part of the phase-out plan. Facebook's server heat is, according to Niels, a corner stone in the new renewable electricity path for FDH. As he introduced the plan for phasing out coal, Niels smiled as he informed the first author that it highlights an important shift for the energy plant. Historically, district heating was produced by harnessing steam left over from electricity generation that

used large turbines, and is now becoming electricity-dependent again, albeit via a different form of excess heat; thus, history is repeating itself in interesting ways. Niels is excited by this electrified reorientation, and he has been working towards a scenario almost solely dependent on electricity in recent years. When presented with this scenario, many of the engineers and board members were concerned about how to ensure the 'security of supply' of the district heating historically produced at the energy plant. Until recent decades, after all, electricity and heating have largely been produced via the burning of compounds and fluids: coal, oil, peat, gas, garbage, wood, straw – all eminently storable commodities. The storage challenges of electricity (as it is increasingly produced from wind turbines) continue to trouble the work of convincing decision makers that stable scenarios can be built around electrified infrastructure without solid fuels, and there are only a few industries in Denmark that produce as much excess heat as hyper-scale datacentres. Even though complementary fuels are still needed, the excess from Facebook is seen as key to driving the local coal phase-out.

Facebook's datacentre in Odense is powered by Denmark's largest electricity 'superhighway', a route that transports electrons to and from, for example, its German and Swedish neighbours. The Facebook corporation has advertised widely that its datacentres only use 100% renewable energy. In Odense, that claim is achieved through the construction of a wind turbine park, and the Facebook communications manager for the Nordic region has stated that the project, funded by Facebook, works to compensate the Nordic electricity grid.[12]

To those involved in the deal, the project seemed a sensible idea. When negotiations between the Danish Government, the electricity supplier, the municipality, the utility of FDH, and Facebook took place at the end of the 2010s, electricity prices were at a record low due to the increasing integration of wind turbines. In policy terms, electrification of the overall energy system, particularly heating systems, was the key decarbonization instrument and, therefore, part of FDH's organizational strategy. Electricity also takes centre stage in much of Facebook's promotional material. In one image published on their sustainability website, a wind turbine towers over the datacentre, neatly plugging

[12] See https://www.energy-supply.dk/article/view/676156/kritik_facebookdatacenter_bliver_100_procent_co2neutralt_med_norsk_vind (accessed on 12 October 2022)

into and powering its operations; however, looking beyond the neatness of the organization's own brochures, the Nordic grid infrastructure that electrifies the datacentre tells another story.

American and European energy corporations have been busy seeking transnational business opportunities since the early 1900s. In recent years, companies from China, India, Korea, Turkey, and Japan have joined the overseas energy adventure (Chen, Tilt, and Zhang 2022). But corporations increasingly operate energy projects transnationally not just through grids but also via the movement of human labour and finance. In Odense, the Facebook corporation has invested in wind turbines built in southwest Norway through Luxcara, a German company specialized in asset management.[13] The investment has been carried out through a "Power Purchase Agreement" (PPA), which works by investing funds in renewable energy development. Typically, it comes with a set electricity price for a set number of years stretching long into the future, thereby allowing the Facebook corporation to be certain that datacentre electricity prices will remain stable during its active years. The MWs produced by the new wind turbines are delivered to the Northern European electricity grid through the Nordpool electricity exchange market.

PPAs are widely used and pushed by Big Tech corporations, and are considered a strategic tool for offsetting carbon emissions (Kobus, Nasrallah, and Guidera 2021). PPAs with added marketing efforts are particularly effective in persuading publics that corporations are producing renewable energy for datacentres rather than merely adding MWs to an electricity market. This 'electrification' is not simply guided by frictionless transition from fossil fuels (Günel 2022). At a financial scale, Big Tech corporations use renewables to electrify their datacentres when, at the scale of the energy current, they are actually powered through electricity produced from any kind of fuel that has been possible to burn at the exact moment in time – often multiple kinds of fuel. When there is no more water in the Norwegian reservoirs used by hydropower plants, and when the wind does not blow, many electricity-producing energy plants in the Nordic region are still fired by coal and other solid fuels. Even if the electricity used

[13] See https://luxcara.com/luxcara-and-facebook-to-add-294-mw-of-new-wind-capacity-to-nordic-grid/ (accessed on 12 October 2022)

is not always 100% renewable, the electricity is financially, therefore also legally, still considered to emit less carbon than burning fossil fuels in Odense.

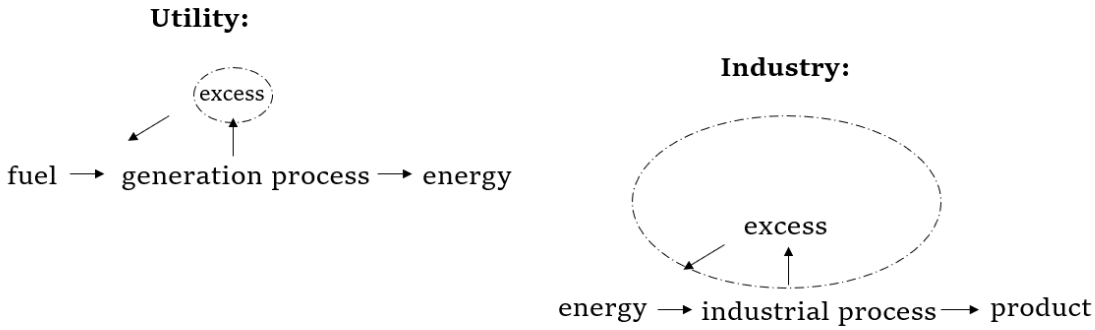
However, the PPAs and the means through which they are advertised as technical solutions by Facebook do not spell out how and with what consequences the electricity is produced. The PPAs reside only in the land of finance. Purchasing wind turbines without PPAs would not have enabled the Facebook corporation to advertise the use of "100% renewables" when the datacentre is materially dependent on all the other fuels burned in supplying the regional grid. Additionally, as one of the engineers from FDH reminded the first author, the geographic areas where wind turbines can be built are increasingly a scarce 'resource' (as they are referred to in the world of renewable energy management). In other words, if the wind turbines were not built through the PPA (the current instalment of compensation for the hyperscale electricity consumption of the hyperscale datacentre) then another institution could have purchased the rights to the territory and produced electricity for the grid simply because more renewable energy construction is considered necessary by Nordic parliaments and a wealth of local institutions and social groups.

The accumulation of electrons from harnessed wind was a major argument for electrifying all energy processes when the first author was doing fieldwork in Odense in 2020. But two years later, during the energy crisis of 2022, the case for electricity had completely changed as energy prices skyrocketed. This was a major cause of concern for FDH as the electricity path for phasing out coal was suddenly much more expensive. For Facebook however, electricity prices will never become a problem thanks to the PPAs. While Facebook purchases electricity from the national grid contractor to the same price as negotiated from initial operation in 2019 due to the PPA, many people cannot pay their monthly electricity bills due to the heavy increase in fuel prices.

Deliberate scale-mismatching is common industrial practice (Liboiron and Lepawsky 2022). It presents infrastructural solutions as solving issues at more scales than what is the case. Facebook's energy consumption at the hyperscale datacentres is so hyper that the energy production through excess heat without infrastructural analysis of production and consumption relations easily could seem to match in energetic and

emissions effects. Yet the excess heat of server air that needs additional electricity to be hot enough for the district heating system produces around a fifth of the total amount of heat for the about 200,000 people that depend on heat from district heating in Odense, while the electricity consumption of datacentres in Denmark already account for 10% of total electricity consumption of the country with a population of around 5,500,000. The effects are far beyond comparison as well as compensation. The opaqueness that comes with the scale of hyper, enormous, distributed datacentres, and all that they depend on, is managed as an industrial advantage.

2. Scales of production-consumption



In legal terms, the datacentre has been decarbonized, but when attending to the wires and cables of the grid, it is another matter. The wind turbine electricity would have been paid for by any institution if Facebook were not at the right place at the right time with the right hyperscale budget for hyperscale finance. Industrial advantage in energy markets is an organizational arrangement that affords this deliberate infrastructuring of different scales. As Niels and his colleagues made explicit, financial and technical infrastructures, including anything that is part of the infrastructure, are rarely the same (see Figure 2). To them, consuming the hot air from industries to limit the total consumption of fossil fuels is the major point of excess heat against which Facebook's instrumentalization of industrial excess works. This is because the boundaries of industrial production are moulded in order to perform circularity rather than adhere to

basic thermodynamics, and because the corporation scales up the benefits of industrial excess to electrification through energy financialization.

Admissions, and the difference between vents and walls

The politics of containment is a character trait of data industrialism as the bloated sales pitches of bursting, innovative, and disruptive technology need appropriate, solid, scalable storage infrastructure (Hogan 2021). But what are the points of admission through which it is possible to enter the contained, built environment of data industrialism? Whereas utility workers engineer vents, datacentres have walls. Jens, another of FDH's engineer utility workers, demonstrated the contrast between admission to the spaces of data production and energy production.

In a recently converted agricultural field next to the periphery of a group of suburban family houses in the southeast of Odense, a new building has been constructed to utilize the excess heat from Facebook. The building is exceedingly modest in size compared to the datacentre to which it is connected via underground pipes. Jens is the project manager for this leg of the network of FDH that houses heat pumps for the consumption of Facebook's server air. Heat pumps elevate the temperature of the server air through electricity as the server air is in itself not warm enough for the network. In that sense, the server air is not actually useful industrial excess until FDH has transformed it. The valves that guide the server air into the district heating pipes can be managed as the Facebook corporation pleases, which is a tool that controls the extent to which infrastructures are connected or closed off.

The building sits on a small parcel of land bordering Facebook's two-meter-high, concrete-based enclosure. Iron bars protrude from the concrete, physically manifesting the more common symbolism of the corporation as a world unto itself.

Image 4. The wall around the Facebook datacentre in Odense.

Sat in the lobby of the new district heating building next to the datacentre, Jens described the processes involved when Facebook's server racks release hot air. The server air is funnelled out of the server building and into this one through a series of pipes connected to the heat pumps. Using a host of subsidiary processes, the pumps both raise the temperature of the air and ultimately secure its conversion to hot water for use in the city and its suburbs. This small building, more of an annexe really, houses the heat pumps, pipes, and a small computer room that manages the flow of hot air from the servers. A few days a week the building hosts an engineer who monitors and controls the heat pumps and the flows of the server air and water.

While it is mostly equipped for engineering work, it has also been fitted out with seats and some displays that showcase the various energy sources that fuel its operations, allowing visitors to identify the fuels used for district heating. Industrial excess heat has long been used for district heating, but this is the first time a curatorial space welcoming visitors and delegations has been established. According to Jens, server hot air from the

datacentre is clearly garnering more attention than other forms of industrial excess, and Facebook has been keen to gift both the displays and materials to be showcased in the building. At FDH's central energy plant, a visitor room similar to this but older also hosts anyone requesting a lecture or a tour that takes them close to the everyday operations of fuel management and energy production. Schools and energy policy delegations are common visitors in both the central and new facilities.

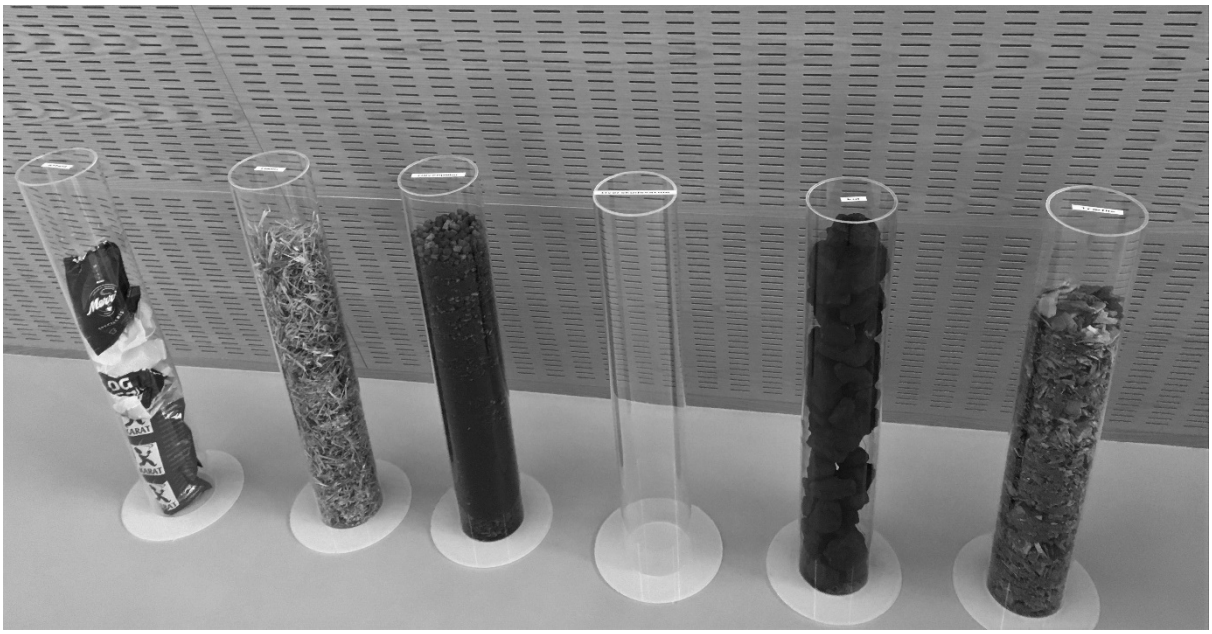


Image 5. Plastic tubes on display in the new building that represent the various fuels used for the district heating.

Next to the entrance door is a display unit with six plastic tubes, each containing a fuel source that is currently being utilized at the energy plant. Sweeping his hand from left to right (see Image 5), Jens lists them as: municipal garbage, straw products, olive oil products in pill form, excess heat, coal, and lastly, on the far right, wood chips. Five of the tubes are filled with material of one form or another, while one of them stands, curiously, empty. This is labelled "excess heat". Its materially diverse character – comprising both industrial excess such as server air and hot air from FDH's own turbines – cannot be represented but is still too materially important to energy production at FDH to be left out of the display. It is placed here to emphasize to visitors that excess heat is part of the line-up of various fuels consumed by the district heating infrastructure to produce district heating.

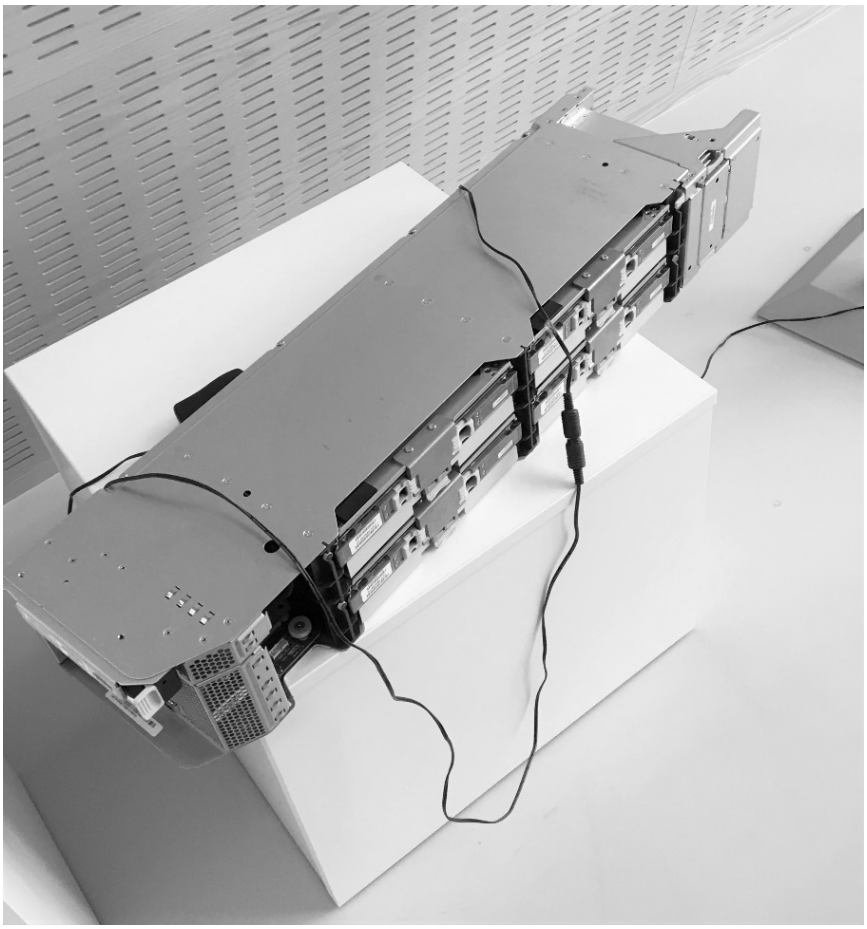


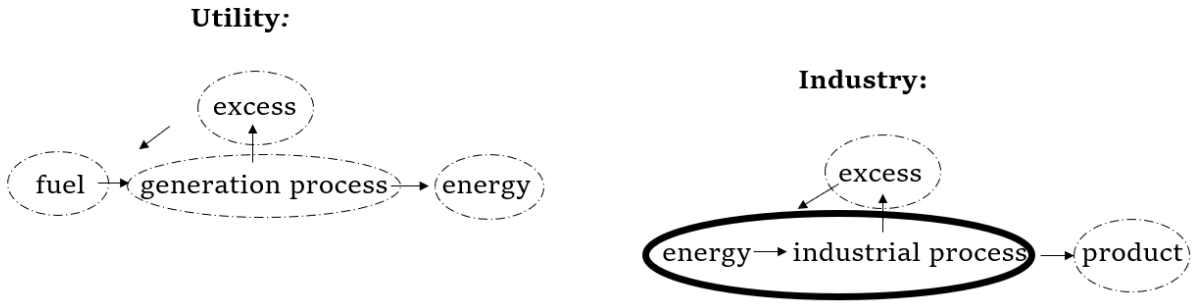
Image 6. Server from the Facebook datacentre on display to exemplify this most recent addition to industrial excess heat.

It was only when Jens mentioned another display that supplements the fuel tubes that the power relations embedded in the visitor room became comprehensible to the ethnographer. Jens explained how Facebook had placed this artefact, a server (see Image 6), to demonstrate the technical origins of the excess heat that could not be represented in the tube. For Jens, these displays are rather irrelevant. He is much too busy making sure the recently initiated flow between the datacentre and this building is operating within normal parameters. A new wing of the recently opened FDH building next to the datacentre was undergoing construction and, at the time, having more heat pumps installed in order fulfil the thermodynamic promise of utilizing more of the available hot air from the servers. But the room displays not just servers, tubes, and posters but also the point that its existence and organization is more important to Facebook than to FDH. As the data production and energy consumption of the building

next door is contained by walls and guards that ask spectators to leave immediately and harass them if taking photos, then FDH's new building makes the industrial excess into sufficient fuel for energy production whilst hosting anyone who wants to admire Facebook's local engagement and global sustainability initiatives. Strangely enough, the sitting area of the room is placed in front of a major window through which visitors can admire the datacentre wonder through the iron bars of the fenced wall.

Neither datacentre workers nor global managers ever have anything to do with operating the heat pumps. This is not necessary, Jens explains. If his team notice a problem from the software monitoring air flows, they simply ask their datacentre contact person for the reason behind the downtime and when the flow is expected to normalize. During the planning and construction phase some of his colleagues met with a contact person at Facebook in charge of its 'energy program'. Apart from that, as Jens put it, they do not need to communicate unless something is wrong with the flow. It is the utility workers' job to make the industrial excess heat hot enough for consumption by FDH, which is a task that does not require much collaboration between the recently converged infrastructures.

3. Admissions of production-consumption



FDH's infrastructure is purposely engineered with lots of vents for the admission of public interest. That is not because the utility workers have to manage the district heating as transparently as possible (which, according to policy, they also do) but because it holds no information on forms of excess that maintain its production and

consumption relations (see Figure 3). The production of energy needs none of the NDAs and security guards that data production is argued to require. On the other hand, when energy consumption and industrial processes of data production are sufficiently enclosed, then the scaled industrial excess from servers takes centre stage as an effective, circular sustainability project.

Industrial excess is a tool, not an overflow, never a surplus

Treating carbon emissions as an externality of industrialism generates an environment in which emissions are the outlier in an otherwise well-ordered world. In socio-economic and policy approaches to climate change induced by emissions from production and consumption relations, the release of toxins is categorized as an externality or, in the language of STS, it overflows into the framing of markets (Callon 1998). In the words of the 2015 Danish Minister of Climate, Energy, and Utilities, the carbon emissions that cannot be accounted for are "a market failure" (Huber 2022). Critical insights into how politicians, as well as business leaders and owners, construct such market framings have historically entered the industrial machine room through analysis of the making of measurable surplus value. Industrial production has several costs, such as fuels and salaries, but is only successful if producing a surplus of capital for the industrial capitalist (Harvey 2020). Whereas 'overflows' enable the measurement of economic boundaries installed between material production and waste, 'surplus' enables economic measurement between centralized material wealth and energy in relation to human labour. Surplus and overflow are concepts with material consequences developed to study economic processes, but as we frame excess here, it is in comparison rather a material with conceptually economic consequences as it travels from the engineers' boundary making for energy purposes to benefit Facebook.

Funnelling industrial excess is the tool of utility workers but, as we have shown, it is also becoming a tech industry tool. In the late 2010s, the Facebook corporation and other Big Tech companies such as Google and Apple started advertising their 'renewable energy projects', placed mostly within the same national territories as their datacentres, with their high electricity consumption. However, despite Facebook telling

the story of Odense as a total infrastructure of wind turbines and datacentre that function independently as it delivers excess heat to the local community, Facebook is not an energy or public utility but a data and finance company.

The extractive endeavours of tech corporations have tremendous effects, including carbon emissions from energy consumption, deprivation of drinking water, pollution from electronic waste, poor working conditions and implemented policies against workers' unionization to better these, platform lock-ins, and reduced governmental power over the organization of social life. Data, just like the traffic of drugs, break the frame of the nation-state as the only sensible container for political analysis (Campbell 2022). As insight into nation-state and tech industry relations shows that current regulation only deals with antitrust policy, ignorance, or deliberate enablement, studying how data travels beyond territorial borders makes it possible to examine the power tools of these industries, which much policy is simply made to enhance.

Conclusion

The feedback loop of excess from industry to the energy system makes the actual emitting system of industrial energy consumption a point of measurement that is somewhat inaccessible to anyone with an interest in effects beyond deceptive sustainability reports. The utility workers' engineering approach to the material of excess as unavoidable when consuming fuels and producing commodities affords a guiding path into studying the techniques of major industries in relation to energy, which go largely unregulated and unchallenged due to their constantly obscured effects. The maintenance and growth of industrial production-consumption relations is an understudied topic in STS; however, this analysis shows that there are several admission points into studying the tools of that trajectory, one of which is excess, which can be labelled as neither production nor consumption but, rather, the mediating glue that holds these material-economic processes together. Such studies can be furthered by empirical and analytical attention to the roles of utilities.

Excess is not an external mistake or intentional design but a tool that exists insofar as it is made to do energetic work. The historical project of absorbing local industrial excess into district heating depends on the boundaries of the production and consumption

relations of industries and utilities. Facebook isolates the movement of excess with a boundary that demarcates its circularity from the company's enclosed industrial production; however, building on this boundary, Facebook's own energy production and consumption functions on separate scales of finance and energy currents. While the district heating system and its utility workers labour to engineer public admission to energy production, Facebook builds admission points that encroach on the heating system, particularly to perform an upscaling of the electrification effects of energy finances. Meanwhile it builds walls around the currents that connect Facebook and its energy effect to its local, national, and regional energy grid, which are not accounted for, in contrast to the energy finances. If the 'production and consumption relations' of data industrialism were studied solely on the basis of Facebook's sustainability report, the inevitable conclusion would be that Facebook consumes 100% renewable energy and has enabled circular heat recovery projects. However, the engagement with industrial excess heat and district heating shows that funnelled server air does not minimize data industrialism's carbon emissions from electricity consumption, nor is the energy current that arrives through the underground to the datacentre in Odense always renewable.

Just as these utility work processes come to benefit Facebook, the vernacular carving out of the figurative components of excess that we have followed also benefits critical analysis. Industrialism depends as equally on its own often inaccessible methods (access only for business partners!) as it does on encroaching on the maintenance tools of public, commonly owned, utilities. It prompts a revisiting of the relational differences between the production and consumption of energy and of commodities such as data. The particularities of utilities need careful attention as some produce for profit and some do not, some are collectively owned and some are still heavily privatized, and because finance rather than merely competitive markets eventually comes to guide interventions in the name of decarbonization.

In Odense, energizing industrial excess at a time when the decarbonization of energy infrastructures is necessary for multiple species survival is reflected in how hyperscale data industrialism is carried out through means that cannot be decarbonized unless levels and modes of industrial production become spaces for potential formal intervention.

Article 2

Datacenter Politics and Welfare Politics: Layers of Reciprocity in the Digital Gift Economy

Caroline Anna Salling
Brit Ross Winthereik

in review, *Science as Culture*

Abstract

The digital economy – contingent on reciprocity between users and technology companies that exchange user data and platform services – has been shown to be product of the limitless extraction of human experience for the exchange of platform access. While the importance of this insight can hardly be underestimated, there are certainly more layers to the digital economy than the exchanges of surveillance capitalism. To illustrate other enabling aspects of the digital gift economy, we use a Danish example of utility workers who are striving to make excess heat from the internet servers in a Facebook datacenter of value to a city's public heating system. We examine the legislative events surrounding the new connection between the datacenter and heating system to reach a better understanding of the industrial base of the digital gift economy beyond the market that undergirds the platform exchange. Big Tech is manifested through gifts, particularly exemplified by reciprocity between companies and politicians. Politicians have insisted on drawing global technology companies in by gifting land, energy, and autonomy, and the companies have neatly packaged not-yet materialized gifts of promised economic ripple effects, thus creating what we conceptualize as layers of reciprocity between interrelated exchanges at platform and base level. Politicians are losing accountability in the realm of welfare politics by placing technology companies and their failed neoliberal responsibilities – to ensure job creation, tax payment for redistribution, and transparency in societal influence – at the center of the vision of how to transform the welfare state for the digital future.

Introduction

Peter, one of the workers in the public heating system for the city of Odense, Denmark, illuminated Facebook's theatre of gifts when he explained the tax dimensions of using heat from industries, including the datacenter industry. He arrived at one of the meeting rooms at the central energy plant of the heating system with a stack of documents and a cup of coffee to introduce the peculiar life of levies and taxes. 'The Danish industry association for public heating systems, Danish District Heating [a form of industry union], takes care of all our policy interests,' he said, while flipping through a heavy book of energy tax paragraphs to explain the most important ones. Through meetings, presentations, phone calls, and collaborative support amongst utilities, utility workers, and association analysts keep each other informed about how policies that affect their work come to be and why they come to be at all. 'One of the recent major events is the elimination of the tax on industrial heat in the new climate act,' he added, before explaining how the elimination came about. Before building a new datacenter in Odense, 'Facebook officials in direct contact with politicians ensured the elimination of the tax on heat from industries.' The result was that Facebook could give the excess heat from servers free to the public heating system rather than selling and paying tax on it, as other local industries have done for more than half a century.

Facebook's involvement in the political process was more spectacular than the effects this event had on the matter of tax – the price of excess heat from local industrial machines is usually minimal and insignificant. The spectacular construction of the territorially most concentrated amount of Big Tech datacenters ever, as all the major technology companies started to build in Denmark by the end 2010s, was a result of Danish local and national politicians that signaled eagerness, for example by the deliberate elimination on the heat tax.

One of the major puzzles of the 21st century is who will step up to take responsibility for the accumulating, centralized power of Big Tech. That question is usually regarded as a critical problem due to the reformulation of market transactions. This is especially so because direct relations between people and technology companies are contingent on gifts of free access and data, unlike traditional capitalist actions that involve economic transactions within markets which often are more transparent to consumers (Fourcade and Kluttz, 2020; Birch, 2020). Humans are computationally surveilled, manipulated,

and punished rather than offered a service (Chun, 2021; Viljoen, Goldenfein and MGuigan, 2021; Zuboff, 2020; Eubanks, 2019; Noble, 2018).

However, there is a critical limit to unveiling these hypervisible forms of violence and wealth (Gilbert and Sklair, 2018; Sedgwick, 2003). To get closer to the core of the responsibility puzzle, we suggest a turn to the societal-material layer that undergirds Big Tech within public infrastructures. For transparent insight into their responsibilities, beyond political rhetoric and marketing lingo, we draw on ethnographic research among utility workers who have had to deal with decarbonization through digitalization and political decisions aimed at enabling the digital economy. The desire to phase out fossil fuels through increased use of industrial excess heat coincided with Facebook's plans to build a hyperscale datacenter in the city of Odense, which opened in 2020.[14]

On the website, www.sustainability.fb.com, 'heat recovery' is offered as an example of how Facebook is extending its economy of gifting beyond the social media and metaverse platforms. On a world map next to dots of green (wind), yellow (solar), and blue (water restoration), a purple dot signals the Odense datacenter, which directs excess heat into the local heating system. The website explains how Facebook has developed this infrastructure to 'donate the heat [of the servers] to the local community' and thus reduce carbon emissions from the energy system.[15] It is not new that datacenters and the energy systems that power them are exhibited online as an invitation to the public to see 'where the internet lives' (Holt and Vonderau, 2014; Hogan, 2013). What is distinctive about this site is that excess heat is used as both a descriptor of how a datacenter operates in connection with energy systems as well as a strategy for how a tech corporation claims to reduce carbon emissions.

[14] We refer to the company's name as 'Facebook' and not the new name 'Meta' because this was the company's name during fieldwork and also because we expect the name is better known than the new one.

[15] Interestingly, the purple dot showing the 'heat recovery' has in 2023 been removed and Facebook does no longer advertise the project, yet the figures of the documents still circulate as explanation for the project. We have not been able to find out what made Meta remove 'heat recovery' as a sustainability success of theirs on the website. https://sustainability.fb.com/innovation-for-our-world/sustainable-data-centers/ (emphasis in italics added by the authors)

Sovacool, Upham, and Monyei (2022) note that one of the reasons for building datacenters in the Nordic countries is to take advantage of 'policy boosts including tax cuts for datacenters.' Their argument about tax cuts underlines the extent to which de-taxation is used as a governance tool in attracting datacenter operators into national territory and, therefore, national markets, which results in various kinds of integrations with energy systems (Bresnihan and Brodie, 2021). As we will show, this is also the case for Facebook in Denmark, except that the eliminated tax on excess heat was to complicate relations: rather than conventional attempts to avoid general corporate tax, market transactions involving industrial excess heat were to be replaced with free delivery – making a sustainability gift of the server air. Additionally, Facebook itself, through relations of reciprocity with Danish politicians, ensured interventions into tax policy.

In this article we analyze how the digital gift economy is manifested beyond platform exchanges and new business models through reciprocity at the base level of public welfare structures, using ethnographic research among utility workers to identify the policy and electricity issues that enable major technology companies access to a base on which platforms can be built, extended and transformed. It turns out that exploring the practices and politics of energy can display the relations between datacenter politics of Big Tech and welfare politics of the neoliberalised state. We first explore the background for current relations between energy systems, policy, and Big Tech in Denmark, which is followed by a presentation of the reciprocity embedded in these relations. We suggest 'layers of reciprocity' as an STS concept that attends to the politics of who will benefit from platformization and indicates how the gifting of things or promises of gifting things is requisite to the continued infrastructuring of major technology companies.

Background: Relations Between Energy systems, Policy, and Big Tech in Denmark

All Danish cities have large, publicly owned heating systems, referred to as district heating. These systems were originally built in the first half of the 20th century to use excess heat from electricity generation to heat nearby residential buildings, swimming

pools, and schools, but eventually grew to service most areas of the larger cities with the supply from fuels burned only for the heating systems. They were largely extended out of the cities in the 1970s to replace households' individual consumption of oil more broadly, as the oil crisis spurred regulation to secure a more efficient use of fossil fuels (Caussarieu, 2021). Danish industries that produce cement, butter cookies, and tin cans have for more than half a century sold excess heat from their factories to supply local heating infrastructures with energy, and energy analysts and scholars work hard to use more of this kind of heat as a substitute for fossil fuels. In 1995, a tax on excess heat was passed as law to ensure that industries would not use more energy than necessary in order to sell excess heat to district heating utilities. In 2021, 3% of the district heating in Denmark came from excess heat from industrial production, while district heating systems supply on average two out of three buildings with heat. Buildings are usually highly dependent on heating systems from September through April to keep their residents, students, workers, and visitors warm enough.

Keeping this heating system up and running while transforming it for the decarbonized society is the task of the Odense heating system's utility workers among whom the ethnography of this article was conducted, through participant observation by the first author over the course of two months in 2020, with follow up interviews. Including interviews with tax officials and civil servants in the energy sector. The research focus during fieldwork was the daily work of the engineers planning and physically constructing the convergence of existing sources of fuel and excess heat produced by the datacenter; this consisted of meetings, site visits, in situ discussions, fixing and maintaining technologies on site, and lunch conversations. The engineers were very welcoming and eager to explain what they were doing. As several engineers kept pointing out the relevance of policy to their daily work, fieldnotes and photographic documentation were supplemented by analysis of reports, white papers, and legal documents. These were given to the first author during the time she spent among the engineers – indicating a strong interest in the regulative framework among many of them – and substantiated by conversations about Facebook's lobby work.

As the utility workers frequently highlighted the impactful actions of politicians, tracing political events became a priority as part of the fieldwork, because it turned out that the engineers' tasks were very much defined by *how* to use the excess heat rather than

whether to use it. The engineers' experiences of the political landscape of relations between policy interventions and Big Tech are, therefore, documented as issues of policy and electricity in the ethnographic vignettes that we present below. The positioning of politicians and their actions in relation to enabling Big Tech is explored through the knowledge and experiences of the engineers, while the politics of the engineers' own work is explored in detail in other articles (Salling, forthcoming; Salling and Maguire, forthcoming), particularly as a contribution to the scholarship on the 'datacenter industrial complex' (Hogan, 2021) and the 'thermopolitics of data' (Velkova, 2021).

In the 2010s, before the materialization of any hyperscale datacenters in Denmark, a new government office of the Danish Foreign Ministry – 'Invest in Denmark' – invited Apple, Google, Microsoft, and Facebook to consider what was needed in terms of placing new datacenters in Danish municipalities.[16] This strategy of arranged marriage was successful in the sense that many municipalities took preliminary steps, such as providing possible locations and changing city plans, to welcome prospective datacenters.[17] This form of managerial strategy by national governance can be described as 'inter-urban competition', which normalizes the momentum of entrepreneurialism by pitting city managements against each other to win the favors of large industries (Harvey, 1989). Local civil servants' expectations of trickle-down impact, and local politicians' hopes for advantageous economic ripple effects in both cities and small communities, are a common entry point for major corporations to establish themselves in locations like Odense (Dale, 2019; Reinert, 2018), which is the focus in what follows.

Studies of the digital economy have shown that Big Tech are intervening in critical welfare-provisioning infrastructures beyond the US (such as health care, education, law

[16] In Odense (Facebook datacenter) and Viborg (Apple datacenter) local politicians claimed that thousands of jobs would be available with the arrival of the tech companies' datacenters https://fyens.dk/artikel/facebook-center-giver-odense-op-til-1000-arbejdspladser-2017-1-19(5) and https://borsen.dk/nyheder/virksomheder/borgmester-holder-fast-apple-sikrer-10000-job-i-viborg

[17] In September 2022, three of Big Tech's datacenters in Denmark are in operation (Facebook in Odense, Google in Fredericia, and Apple in Viborg) and four are under construction (Facebook in Esbjerg and Microsoft in Roskilde, Køge, and Høje Taastrup).

enforcement, and energy) (Phan *et al*., 2022; Birch and Bronson, 2022; Hendrikse *et al*., 2022; Maguire and Winthereik, 2021; Sadowski, 2020). Additionally, Scandinavian welfare states are increasingly encouraging public and corporate infrastructures to converge, thereby outsourcing key welfare tasks while claiming to produce economic value through increased efficiency and competition (Salamon, Lex, and Friberg, 2015). 'Welfare' has changed since the 1990s with the transformation of the self-sustaining welfare state onto increased global economic competition as a means for creating the new welfare state built on the pillars of industrial, corporate tax (Pedersen 2018).

More than ever before, industries are by politicians positioned as welfare creators through jobs and taxes. In this vein, many government ministers are smitten with the 'hype of economic gains from digital transformation' (Hockenhull and Cohn, 2021) and are keen to implement 'public disruption' (Collington 2022) and 'the fourth industrial revolution' (Schiølin, 2020), and also, for example, venture into formal partnerships with Microsoft on AI strategies. The political consequences of expectations, exchanges, and enrolling societal groups as foundational to digital platforms can be studied through the resulting reciprocities. Thus, this analytical intervention provides an entry point into studying not only *which* material things are exchanged but also *who* take part in these exchange relationships, and who do not.

From Gift Exchanges to Layers of Reciprocity

In response to the social scientific late-90s obsession with defining globalization as a universal process largely resulting from the development of digital information technologies, Tsing (2000, p. 342) asked the enduring question: 'Might a different kind of reading practice reestablish the potential for appreciating multiple, overlapping, and sometimes contradictory globalisms?' Indeed, the major connection point between STS and anthropological studies lies in problematizing the view that universal wholes of science and technology, nature, and culture exist and can be adjudged fully by those with enough power and expertise to do so (Strathern, 2004 [1991]; Vivieros de Castro, 2004; Mol, 2002; Latour, 1988; Haraway, 1988). With empirical specificity, such studies have demonstrated how the world is materially layered with a wealth of interesting and important differences rather than simple univocal correlations.

The production of singular, powerful worlds requires a great deal of co-ordination, stabilization, and aligned similarities between the involved parts (Gad, Jensen, and Winthereik, 2015), which is certainly an exercise undertaken by Big Tech when scaling their businesses to cover more of both territories and social life (Pfotenhauer *et al*., 2022; Seaver, 2021; Tsing, 2012): for example, when the digital platform is scaled not as merely one component of social life but as *the* universal container for all social life and its relations, activities, and engagements.

The studies of multiplicity in social and material lives, and the differences in the worlds that contain them have confirmed the importance of paying close attention to experts', practicians', and locals' own terms for the things they do and the things they experience. Facebook's reasons for strategically offering donations, gifts, and contributions to local communities certainly must be front and center of analysis and documented with a keen eye to the multiplicities that are packed away when platforms construct these single digital economy gifts, such as users' immediate, monetarily free access to platforms. For more than a century, anthropological studies have documented the processes of material exchanges in diverse locations, typically by categorizing different kinds of reciprocity: what, how, and when things are exchanged, how they are of mutual benefit, and which actions are expected from the gift exchanging parts in relationships, eventually turning debts from received gifts into returned gifts (Gregory, 2015 [1982]).

Studying not just the construction of reciprocity amongst groups but also several intertwined reciprocities is especially anticipated in the analysis of how capitalist value is made through gifts. As documented by Tsing (2013), commodity transactions depend on gifts, which means that gifts can exist both as something exclusive, outside capitalist supply chains, and enrolled into them as commodities. This aligns with how social scientists seem to agree that economic value is increasingly generated through the digital economy and financialization that is dependent on intangible goods (Dobeson, 2021; Birch and Muniesa, 2020). There are many moments in the life of materials in which gifts are 'more-than', 'never-really', or 'not-yet' a commodity, and shaped differently from commodities, which are usually defined as residing within economic

structures.[18] Gifts are multiple, and they produce different social relations (Graeber, 2014; Strathern, 2012).[19]

Layers of reciprocity can be described as the multiplicity of exchanges that exist in heavily scaled relations between technology companies and the public groups they rely on for existence, growth, and endurance. The exchanges going on at one layer, the platform, are already well documented. 'The platform' was originally the computer industry's own term to separate the connection between company and interface, exemplified by Microsoft as the company and Windows as the interfaced platform (Plantin *et al*., 2018). Facebook attempted the same split between business and product with the launch of 'Meta Platforms' to signal that Facebook is only one of the company's several platformed products. Platforms work through exchanges of gifts of data and functionality between technology companies and users, whilst social relations are appropriated for maintaining and scaling the exchanges (Fourcade and Kluttz, 2020; Zuboff, 2020; Velkova, 2016; Gregg, 2015). Thus, the business case of the digital economy is not only dependent on, but fully structured around social relations through the appropriation, accumulation, and restructuring of these relations by the userbase.

Gifts are the backbone of the Facebook platform, and the reciprocity of access to platform services allows the company to govern its users through a range of different tools: algorithmic governance; judicial labor and ambiguity about rules; isolation by removal/suspension/blocking; constitutional legitimation resting on 'community standards'; and the model created by the combination of all these (Schwarz, 2019; Srnicek, 2016). Just like historical industries, Big Tech are becoming not simply 'internet landlords' but also real estate owners on a major scale (Greene, 2022). Thus, Big Tech's

[18] Gifts are dependent on social connections and relations, and, in contrast, commodities on use and exchange value. In supply chains, Tsing (2013) shows, materials only take commodity form briefly through logistics, but can mostly be identified as gifts before and after commodification. Tsing ties commodification and gift-giving together by arguing that gifts as social relations are required for capitalist commodification to take place at all.

[19] Strathern's argument (2012) is one that attempts to show that the economy is not always the only major driver for gift-giving, of which our analysis is not an example. We conclude, in line with Graeber and Tsing, there are many different kinds of gifts. If we look at gifts this way, we begin to understand why gifts are rarely given anonymously, as they are supposed to make or keep friends (Pipyrou 2014; Callon and Latour, 2009; Rio, 2007). This is likely the reason many scholars return to Mauss' (2016 [1925]) seminal anthropology that set out to understand how the object of gifts is to create social entanglements.

participation in the free software and open source movements has never been anti-capitalist liberalism but rather a remodeling of liberal capitalism (Kelty, 2008, 2013), efforts that are crucial to making the Silicon Valley mythology (Dourish and Mainwaring, 2012), narratives of freedom through computing (Gregg, 2015; Coleman, 2005), the anarchocapitalism of cryptocurrency (Flood and Robb, 2017), and the digital capitalism with which activists, artists, platform users, researchers, and politicians are still trying to come to terms.

In addition to the politics and relations of the platform, the digital economy is also materialized in what we refer to as 'the base.' This layer of reciprocity is not yet explored thoroughly but will receive analytical attention in this article. If the platform is a structure that reaches as high over surface level as an oil rig whose location and purpose as a structure can be established from many miles away, then the base is its securement to the ground – not merely built first but anchored, maintained, replaced, and often enforced when the over-water-level structure needs more fixation to stay put and fulfill its purpose.

'The installed base' is a concept first used to identify the systems in place on which new public information infrastructures are built that highlights how it makes more sense to program on existing hardware and software rather than build from scratch (Aanestad *et al*., 2017). Yet the 1990s information technology term of the installed base have, by the power of Big Tech, increasingly come to refer to technology companies' market value in relation to numbers of users. The transformation of the general meaning reflects the general transformation of information technology originally as a networked communications project of states onto a big business project (Edwards 1997; Hughes 1987). The base layer of platforms, as we attend to it here – in contrast to the installed base of information infrastructures – is more politically relational than the spatial and temporal dimensions of 'the parts that were already there before'. If the platform is politically more contingent on social relations and exchanges of service and data (the making and keeping of as many users as possible) than on interoperable, sophisticated technical systems, then the base layer of platforms is also so much more political than mere instrumental infrastructural technicalities.

'Infrastructures do not grow *de novo*,' Star (2010, p. 611) observed; rather, they inherit and reject traits from technical components, routines, compounds, and affordances that have been left on the ground for anyone to build upon: for example, a platform. And it is certainly easier to build a major platform on top of a base whose components are common things, collectively owned and free for all the technologies of the welfare state. Neoliberal policy interventions in welfare states are characterized by how they govern through technological private instruments rather than through formal political institutions (Larkin 2013). In this sense, the co-dependence of not one, but multiple layers of the digital economy can be unraveled by documenting the contrasts of its parallel, multiple gift exchanges. Who are the receivers of the gifts of the digital economy beyond the platforms and their governed users? What do they give and what do they get?

Exploring the Digital Gift Economy through Utility Work

1. *Policy issues: Elimination of an energy tax*

'Electrification is the future for all energy producing and consuming systems,' the first author was told repeatedly whilst spending time with the engineers planning and calculating the future for the district heating in Odense – for example, by Peter, who has worked on energy taxes for many years. Peter was keen to talk about how tax on excess heat matters in their daily work, especially when planning the district heating infrastructure, as new climate policy had pushed for more electrification of heating in order to phase out fossil fuels.

Since 2019, the Danish Parliament has initiated a number of laws within the Climate Agreement on Energy and Industry.[20] Among these, 'Green Heating for Danes' promoted the diversion of hot air from industries into district heating systems all over Denmark. The agreement emphasizes that the collective model of district heating, which has ensured stable energy provision for many decades, must be provided through 'sector coupling'. The stability and reliability of energy provision was now also to become

[20] In this policy text, excess heat is referred to as 'surplus heat' but in most policy, academic, and white papers this form of heat is titled 'excess heat'.

sustainable through this policy. The Danish Energy Agency is tasked with handling the practicalities of the 2020 climate policy (such as tax elimination), including enforcing an energy efficiency scheme in which companies can be certified, thereby becoming fully exempt from paying tax on excess heat. In the policy documents, this is presented as a simplification and, indeed, also a full elimination of the tax since all industries can get certified by following the energy efficiency recommendations within the scheme. Ultimately, the change of the tax policy came from the desire to decarbonize industries and energy systems. Accordingly, district heating systems would now have to produce not only the same amount of energy but also extend the systems but with lower carbon emissions.

Aligning district heating operations with political goals, however, requires considerable expertise. 'Before the excess heat tax was eliminated and replaced with a certification scheme in the climate agreement policy, it had its own section in the tax law,' Peter said. The law on excess heat was also part of the coal tax law, the gas tax law, the mineral oil tax law, and the electricity tax law. As we started to look into the more than 1,000-page-long handbook of tax laws that he brought to our scheduled meet-up, he laughed at the strangeness of someone showing interest in this stuff: not only is district heating usually perceived as boring infrastructural work but how much more so the tax law![21]

The workers employed by the district heating utility often participate in formal public hearings on new regulations, such as the eliminated tax on excess heat of which Peter was responsible for attending to the hearing process.[22] He clarified that this kind of work belongs to what they classify as 'lobby work'. When the Danish parliament announces a public hearing for a new policy, district heating companies are invited to participate in lobby work along with many other companies, organizations, and formal

[21] Tax governance is a topic that many other ethnographers have studied. One major insight is that tax governance generally emerges through a heterogenous assemblage of competing and collaborating actors and ideas rather than simply being a service and welfare state requirement managed by the public authorities (Jørgensen, 2021; Elmi, 2021; Makovicky and Smith, 2020; Björklund Larsen, 2017; Boll, 2014).

[22] According to the official statement of the parliament, the following defines a public hearing in Denmark: 'Ministries send law drafts for hearing before processing in the parliament through which affected associations, organizations, communities, etc., are asked to give written feedback (hearing answers) on the bill.' (translated by the authors) https://www.ft.dk/da/leksikon/hoering

groups that might have interest in, or have important remarks to make about the new policy.

By making the form of lobby work clear, Peter opened for discussion Facebook's role in the changed regulation on excess heat. Through his remarks on the tax, it became clear to us that there could be no tax on the commodity of excess heat if Facebook were to make a gift of excess heat, which was the corporation's wish from the early stages of the negotiations. His answer suggested that that kind of lobby work is not the sort in which he can participate, or, in other words, it would have taken place *before* the changed energy policy was formulated in the new Climate Act, rather than as the result of a public hearing. 'Obviously, that is not something we can see in the text anywhere,' he said, after which he explained the plethora of examples of undocumented lobby work in the manuals of tax law. For example, he continued, 'in many instances it is quite clear but unstated which agricultural company has influenced which tax law on farming.' The consequence is that it is impossible to document how, in what capacity, by which detailed means, and the extent to which Facebook was involved in the elimination of the tax.

Peter's remarks show, however, that differences in the scale of organizational power afford differences in scale of the policy impact. Facebook's successful *informal lobby work* took place prior to policy development as a result of direct contact with politicians, behind closed doors, whereas the utility's *formal lobby work* could ever only take place in the public process of hearings that respond to already suggested policy.

The engineers and the managers of the district heating utility must accept the public hearing format as the only channel for their lobby work. In contrast to Facebook, the utility's lobby work is only formal and never informal with direct contact to politicians. Since the opening of the datacenter the district heating system has been extended by various construction projects and investments in order to utilize the excess heat. It is not clear which parts of this construction have been financed by the Facebook corporation and which by the district heating utility (thereby eventually the municipality) because the contract is confidential. But the engineers confirm that the new building housing the heat pumps next to the datacenter is fully owned and financed by the district heating utility. It is only the electricity powering the heat pumps that is currently supplied by the Facebook corporation through its confidential contract with

the grid operator, although should Facebook pull out, the facilities can be used for another form of electrified district heating production, Peter said reassuringly. Even so, the architect-designed building with state-of-the-art heat pumps was a large investment for the district heating company's budget. Meanwhile, the electrification momentum enabled Facebook to construct direct relations with Danish politicians on energy policy matters.

2. Electricity issues: Facebook's unlimited consumption

The engineers of the district heating utility have recently installed many large heat pumps to increase the server air temperature sufficiently to meet the requirements of the local system. These have been positioned next to the datacenter but also in other locations including the central energy plant, which for decades has been fueled with materials such as coal, straw, and municipal garbage. The heat pumps can be used for many different kinds of excess heat, including hot air from the burning of household waste and wastewater from the nearby waterworks facility. However, Peter mentioned that legally, excess heat is not the same if sold by an external industry or simply used from one of their own boilers as a result of burning garbage. As noted above, excess heat from industries in the past has been sold and therefore also taxed to ensure there is no overproduction and therefore overuse of fuels. With reference to the electricity tax and the excess heat tax, he commented that the parliament is also changing the taxes because the grid is getting more and more electricity from wind turbines. He ended his walk-through of tax history with the conclusion that this policy is certainly regulating their behavior as an energy utility, requiring them to change their facilities in Odense, integrate with Facebook, and install all these new heat pumps – needed because the server heat is not warm enough for the heating system.

When on a tour of the heat pump facilities, another engineer, Jens, remarked with a grin that the excess heat from the servers is more lukewarm than hot: a production project rather than something ready-to-be-used. In 2017, the municipality-owned district heating organization decided to invest in 24 MW heat pumps in order to use Facebook's excess heat, and in 2019 an additional investment in 20 MW heat pumps was made, which included the large new building for housing the pumps immediately adjacent to

the datacenter. Peter's account of the tax on excess heat shows how the eliminated tax led to reorganization as well as new investments within the district heating system, while, in contrast, Jens' insights about the electricity connections showed not only the gifts at the base layer of politics but also those related to energy currents. The changed policy written into the climate agreement has clearly been successful in incentivizing the convergence between datacenter and heating systems, with the use of the server heat enabling electrification of the system – the major contemporary energy policy trend for decarbonization. But if the district heating utility is fueling the heat pumps, how will they be remunerated for their efforts?

Facebook has offered to supply the electricity that the heat pumps use, in combination with its own electricity supply for the datacenter. On their sustainability website and on posters placed inside the new district heating facilities, the corporation advertises the use of 100% renewables from two wind turbine farms in Norway to fuel both the datacenter and the heat pumps. It works like this: Facebook has entered 'corporate power purchase agreements' (CPPAs) whereby it purchases wind turbine construction through an external asset management firm. The wind turbines are added to the Nordic grid, which also supplies the city of Odense. Thus, barely a gift to the district heating system, excess heat and, thus, the energy project, is intended as a gift to the grid rather than directly supplying the datacenter, as it might seem. In this enactment of gifting, however, emphasizing the energetic transactions does not support the image that Facebook wants to create in which the datacenter is directly serviced by wind turbines – only supplied by wind energy – rather than the coal, oil, gas, garbage, nuclear, hydro, and wood-fired energy plants in the Northern European grid that produce electricity when the wind does not blow enough to supply. This is an actual image that circulated as a model graphically designed by Facebook for the poster in the new heat pump build of the utility and for its sustainability website. In Facebook's official model, the datacenter is placed right between two wind turbines that plug directly onto the data storage facilities.

When the news of the wind energy projects in Norway became public in 2019, the only problem discussed was how the production of electricity in Norway but used in Denmark would look bad in what was referred to as Danish 'climate accounting' in terms of living up to geopolitical climate goals. The Minister for Energy, Utilities, and

Climate refused the problematization and accepted the financial energy compensation: 'It's good for the climate worldwide, and the climate does not care where the wind turbines are constructed.'[23] Based on the government's formal acceptance of financial compensation via the constructed wind turbines, Facebook went on to advertise that its datacenter in Odense is carbon neutral.

In that sense, the electricity consumed by the Facebook servers is made intangible through accounting instruments. Moreover, the financial agreement enables Facebook to pay the same secure and set electricity price for more than a decade, in contrast to all the other energy users in the country who, since 2019, have only received increasing bills for everyday subsistence use. This could be viewed as external to the activities of the datacenter operators, but a report published in 2022 by the Danish Datacenter Industry network on the use of excess heat points elsewhere: 'This [heat recovery] provides optimal conditions for datacenters to become a natural and important part of the heat supply in the district system, directly contributing to more sustainability, achieving greater CO_2 reductions.'[24] As the datacenter and public heat production connections are structured for full integration, the actual energy and emissions impact of the digital economy is hidden behind a shower of potential gifts, not yet received by energy users, producers, or by anyone whose life conditions are vulnerable to climate change induced by heavy energy consumption.

The Reciprocity of Politicians and Technology Companies

Facebook's promised gifts are accepted with much appreciation by Danish politicians. To pave the way for Facebook, a report commissioned by the corporation itself was published by the industry analysis company, 'IHS Markit', in 2019. The report focused on the 'economic contribution' of Facebook's three datacenters in the European Union and offered quantitative analysis of various parameters based on numbers delivered by Facebook itself. These included purchased equipment, wages, construction work, and

[23] https://www.altinget.dk/artikel/facebook-bygger-datacenter-i-danmark-men-vindmoeller-i-norge-klimaet-er-jo-ligeglad

[24] https://www.datacenterindustrien.dk/knowledge-hub

models that abstractly showed capital flows between units to highlight the part played in the Danish GDP by estimated increases in spending by local employees and overall expenditure. The report is presumptuous enough to suggest an estimated GDP contribution and economic gain as a result of everyday purchases by its employees, of which there were not as many as promised and some of whom had formerly worked for the district heating utility but were offered a higher wage at the datacenter.

Such calculations tell more about the general economic strategies of politicians and how to cater to them rather than providing any kind of informed reality, as GDP metrics are always partial and limited (Murphy, 2017); however, the Danish authorities were convinced by Facebook's case. There was press coverage of Odense's mayor approving the news of the final agreement with the statement: 'To me this is the large happy smiley and thumbs up because this really is an important turning point, and I see enormous prospects for the city.'[25] Similarly, on the datacenter's opening day in 2019, the Minister for Energy, Utilities, and Climate commented on his visit with a post that could easily mislead users into thinking that a number of new wind turbines built in Odense had something to do with Facebook: 'Busy day in Odense. The opening of Facebook's green datacenter and visiting the harbor with the new wind turbines!'[26] The post included four photos, and in the first he winks in front of a wall plastered with the Facebook logo while his index finger positioned next to his head confidently points upwards.

In addition to enrolling politicians in claims about providing new employment opportunities, renewable energy construction, and compensation, the Facebook corporation characterizes its local efforts in Odense in terms of investments and financial donations. It particularly emphasizes the 'Community Action Grants Program', which has donated large sums of money to entities including the local 'Save the Children' group, a hacker space, VR headsets for local schools, public schools' STEM education, and an NGO arranging activities to get more schoolgirls interested in engineering. In 2020, 190,000 USD were donated to these and similar public institutions

[25] https://www.dr.dk/nyheder/penge/odense-borgmester-om-facebook-nyhed-happy-smiley-og-thumbs (translation by the authors from journalistic interview)

[26] Quote from Dan Jørgensen's Facebook post translated by the authors.

and NGOs in Odense, and each year the grant application reopens for new donations. Applicants are guided through webinars and instructions in how to apply for the funding. 'We are happy to have a positive impact on society,' the datacenter manager answered when asked about the grant program by a local newspaper. This program is an example of a form of charity where economic funding is donated to groups that are estimated to be in need of assistance and, importantly, strategically smart to support (McGoey, 2021).

The donations targeting schools and tech extracurricular activities are not accidental. Compared to historical forms of philanthropy, tech philanthropy is novel in that the corporations involved concurrently assert their own digital expertise and products to create societal impact and secure users for the future (Henriksen and Richey, 2022). Indeed, transnational donations have for decades been a well-used business model by tech corporations (McGoey, 2016), as even small sums can have political impact because when such support becomes normalized, sudden withdrawal or failure can be devastating. In this context, of particular relevance is how large, strategically selected donations also do the work of redistribution. This resonates with how the national governments and municipalities of welfare societies are expected to ensure certain levels of redistribution.

However, technology company-driven redistribution of welfare takes a different ideological route than that advanced by a sitting government, and it is not democratically sanctioned. If companies and foundations donate enough to targeted projects, institutions, or organizations, then the allocated public budget does not have to be spent, the argument goes, and can be used elsewhere. But, in practice, public budgets are often cut instead of redirected (McGoey, 2016). The donation gifts in Odense go to educational areas that the local municipality is officially responsible for managing and budgeting. Facebook, however, intervenes in that as a result of the acceptance by both national and local politicians – with many 'happy smileys' – of the gift of promised but not realized national and local economic ripple effects.

Odense's schoolgirls' might be less critical of Facebook than most other citizens due to the success of the local donations in augmenting coding training and VR headsets. That does not, however, result in establishing a direct line of reciprocity. In the strategic framework of these businesses and the politicians themselves, materials gifted to

schools and students – like the heat directed to the local heating utility – are all numbers in economic calculations that benefit the companies rather than citizens or utility companies, despite being presented as providing welfare by industrial economic means (see Figure 1).

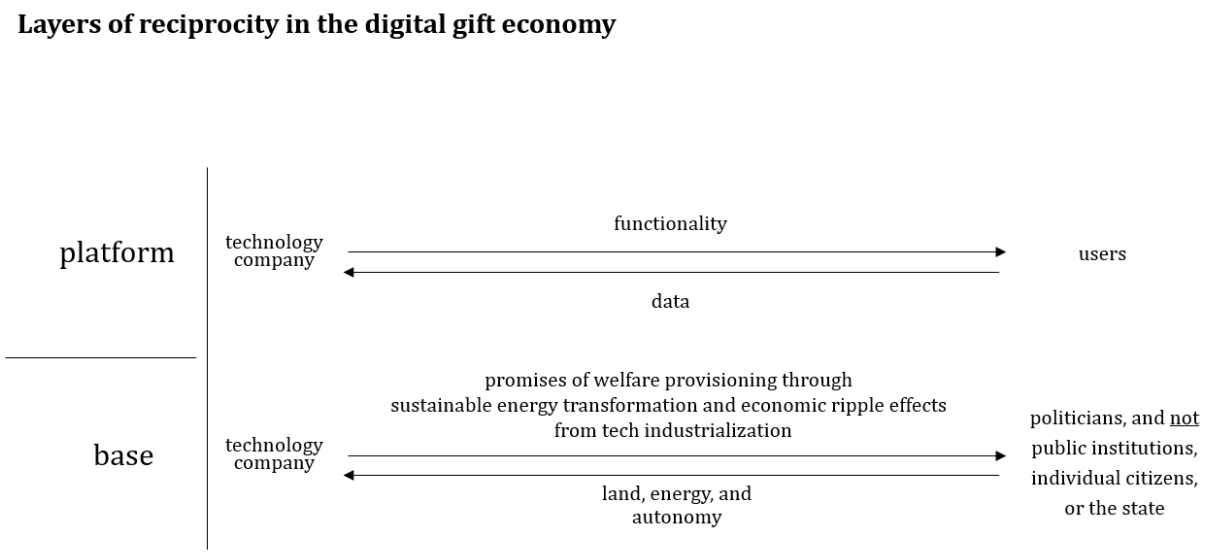


Figure 2. Layers of reciprocity in the digital gift economy.

The Facebook theatre of gifts is finally crowned by the server air, as it can be reported that the effect of using the air for district heating does not minimize the carbon emissions of Big Tech but is, rather, orchestrated as another gift. Still, it is advertised as one way the Facebook corporation is involved with the local efforts of what are commonly referred to in industrial lingo as 'sustainability initiatives' for which reason many Northern European municipalities and states are eager to host datacenter construction (Libertson, Velkova, and Palm, 2021; Vonderau, 2019). The public representatives responsible for the invitations and their reactions to the final outcomes of datacenter construction comprise a research field that is certainly understudied. By placing technology companies and their failed industrial neoliberal responsibilities – such as job creation, tax payments, and transparent lobby work – at the center of the vision of how to ensure the future of the welfare state, politicians put themselves in a position whereby they lose accountability as democratic representatives.

As a response to the promises that never materialized, two Danish city council politicians of Viborg made a public statement in 2021 to conclude that the Apple datacenter built few years before would not live up to their expectations. The promise of 10,000 jobs seemed nearly excruciating when one of them commented 'even 1,000 jobs seems impossible at this stage.'[27] This is the only public statement on the welfare political failure of the datacenters in Denmark, yet the Apple datacenter is still in operation, and more Big Tech datacenters will open in the years to come.

It took many months of construction work, trial phases, and the major financial outlay of employing external constructers, architects, and energy analysts to make the server heat useful to the district heating of the city.[28] New climate policies calling for the electrification of all energetic processes state that any available excess heat from industrial production must be put to greater use in the future. But this excess heat from the Facebook datacenter is not just there, available, and ready to be used; rather, it is the product of considerable electricity generation, policy intervention, and lobby work. In the examination of these layers, it becomes apparent that digital economy gifts establish tights networks of social and political connections between global tech corporations and welfare-providing infrastructures (such as energy systems and education) due to the reciprocity between the technology companies and politicians that strategize on how to ensure industrial, economic growth. The forms and effects of such relations is an issue we have only just begun to understand.

Conclusion

This article departs from the well-documented analysis of data exchange relationships driving the success of Big Tech platforms and supplements it by taking into account observations of another set of practices that uphold platforms. These practices are

[27] https://www.computerworld.dk/art/257797/viborg-vi-har-ikke-faaet-det-ud-af-apples-datacenter-som-vi-havde-forventet

[28] The literature on gifts simultaneously builds on, speaks to, and challenges notions of freeness and altruism, in which it has been debated whether gifts are ever free or if they always must be returned somewhere (Cross, 2014; Strathern, 2012; Laidlaw, 2000). Our focus here is on documenting the multiple layers of reciprocity in the digital economy rather than judging whether the gifts are truly free gifts or not.

exchanges beyond the platform itself and can be characterized as 'layers of reciprocity'. The digital economy is contingent on reciprocity between companies and users through the exchange of two gifts – data and platform services – meaning that its success is often reduced to the limitless extraction of data due to users' engagement with free platform services. But the experiences of utility workers at a public heating system in Odense, Denmark demonstrate that there are further reasons for Big Tech's success and their continued territorialization. We have shown how the changed energy policy can form a window into a whole range of interactions and exchanges going on between Big Tech and actors of the political arena, thereby identifying another layer of reciprocity in the digital gift economy.

Layers of reciprocity clarifies how business models in the strategic digital gift economy extend to more areas of social and material life than the exchange moment between users and technology companies, thus providing a framework for analyzing the diversity of reciprocal relations within a single phenomenon. Attention to these reciprocities exposes how fewer than promised get something out of Facebook's intervention into national tax law, energy consumption and production, and local land use. This contribution locates gifts (excess heat, electricity, advertisements, reorganized educational programs, promises of economic ripple effects at both local and national level) that do not come to provide anything near what was promised and require much work, financial investment and reorganization by the locals. Thus, we suggest the actual receivers of the gifts from Big Tech, politicians, as figures of precarious accountability.

In the neoliberalized welfare state, accountability is instituted through regulated market exchanges, and our analysis shows that when the monetary value of these exchanges is taken out of the governed equation by the digital gift economy, politicians remain convinced that these new, non-market exchanges have the same effects through inscribed values as collective exchanges. The political distance between non-market digital economy gifts and communal sharing and distribution needs more attention. The question for analysis is not only how to govern Big Tech corporations but also how corporations such as Facebook already subtly govern much more of society than simply

the business of their own corporations by building on societal welfare infrastructures with promises of redistribution.

As the digital gift economy is, beyond platformization, transforming the kinds of industrial capitalism that have been formulated in and supported by decades of government policy, and the governance instruments that are used in this endeavor are similarly applied to energy and policy systems, attention must be paid to who enables whose agenda, and who are the few that actually get something out of the listed promises – if they materialize at all. Indeed, it is not far-fetched to conclude that major industrial complexes such as Facebook are not societally valuable in themselves but are made politically valuable through gifts that contain more intangible promises than material welfare effects.

Article 3

The social life of scientific laws: Colliding market dynamics and thermodynamics in engineers' decarbonization work

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submitted, *Social Studies of Science*

Abstract

This article argues that scientific laws are sufficiently material to collide with effect on the site of a city's publicly owned heating system, principally with the work of engineers substituting fossil fuel-based technologies with electricity-dependent ones. The engineers in question are working towards utilizing excess heat from servers in a recently built Facebook datacenter, but their thermodynamic efforts are being interrupted by the need to deal with new energy and climate policies that are putting the city's heating system up for competition. Following Stengers' writings on the history of constructivist knowledge events, I analyze the scientific laws as they come to have impact far from academia. Based on ethnographic fieldwork among the heating engineers, the article shows how the two scientific laws, energy conservation (thermodynamics) and economic competition (market dynamics), meet in a collision event between pragmatics and performativity, the physical effect of which has interrupted the engineers' decarbonization work. I also demonstrate that when major tech corporations are only governed by their concern with market effects, such as their coveted monopoly, environmental effects become a problem to be solved by the companies' own, limited, energy-market initiatives. The contrast between the two laws – along with how the arch enemy of competition, monopoly, is handled in the worlds of energy and corporate governance – shows how dealings with ineffective corporate decarbonization have much to learn from the utility work of public heating systems.

Introduction

This article shows that scientific laws are entities that move between industry, policy, utilities, and academic science and can crash when any of them meets another with enough force. The material conditions and components of scientific laws need to be analyzed for us to reach a better understanding of the knowledge base of political decisions on issues of critical concern, such as how to slow down emissions-induced climate change. Not only are scientific laws mobile, they also interact and in practice sometimes collide. Policy enablement of major, heavy, energy consumption and economically monopolizing tech corporations offers one such contemporary window onto the social life of scientific laws.

Descriptive science institutions, commanding policy chambers, instrumental industry offices, explorative citizen science outings, instructive classrooms, and maintenance-focused public utility infrastructures are all sites in and between which scientific laws live their social lives. They are usually treated pragmatically as being in the service of society but sometimes positivist enlightenment legacies kick in and they get packaged as neutral stable objects that have never shifted in form – as godlike entities that with no uncertainties will determine forever the paths of all other life forms. Centuries before the advent of social scientists, thermodynamic theorists established that objects have relation-making powers and constructive materialities (Barry, 2015), but sometimes the things of science are still treated as ideal types found in nature. That is often how policies enable science, even when the scientists who created or inherited these entities repeatedly insist on showing that they have developed in specific concrete settings, and in conditions with levels of uncertainty. However, energy work is pragmatic work.

Science and Technology Studies (STS) has unraveled how these laws are practiced by linking up, for example, the relations between energy and thermodynamics, and economics and market dynamics. Practical contrasts stand out when STS literatures on the social and natural sciences are juxtaposed. *Competition* as an economically performative law of markets (Callon, 1998; MacKenzie, Muniesa, and Siu, 2007; Polanyi, 2001 [1944]) is in marked contrast with *conservation* as a thermodynamically pragmatic law of energy (Barry, 2015; Daggett 2019; Stengers, 2005). Performativity

and pragmatics deliberately make and unmake material worlds but with different means and ends. This article argues for attention to knowledge relations across disciplinary boundaries as well as the effects of these laws outside of academic institutions (such as beyond scientific publications and the laboratory): how and who makes them perform and pragmatize. This is important because scientific laws have major impact, particularly in collision events between performances and constructions taking place in the landscape of policies, industries, and infrastructures of public interest. The financialization and economization of public utility distribution, unambitious emission reduction goals, and decarbonization work – as it is increasingly made a policy issue that will be solved only by profitable, technological innovation – together highlight the need for examination of such collisions.

In common with competition, energy conservation and thermodynamic accounts of energy are topics understudied by ethnographers and social theorists (Barry, 2015). Perhaps, ironically – because, as Smith shaped the ideal of competition in the 1700s, it is supposed to work as an invisible hand – most social studies have deliberately not shown competition in action (Werron, 2015) but instead examined idealizations of competition (for notable exceptions, see Narayan, 2023; Türem, 2011; Zuiderent-Jerak, 2009, 2015). Actor-Network Theory made such analytical interventions into the idealization of competition by attending to relations not as competing parts but, on the contrary, as alliances between parties that impose and reject identities on each other and then stabilize them (Callon, 1986; Knorr-Cetina, 1997; Latour, 1990).[29] Yet making competition happen takes considerable bureaucratic policy work (Türem, 2011) and, additionally, when interlocutors identify how they are forced to organize to deal with competition, then conceptual intervention does not prove analytically sufficient. This dynamic of competition is not merely an invisible hand, hook, or any other organ or tool; rather, it travels as a result of considerable force to perform the social life of neoliberalized markets. The spheres of planning, regulating, and working with energy are embedded with just as many dimensions of power plays as any other area of contemporary societies (Bell, Daggett and Labuski, 2020). By ethnographically studying

[29] In his book, *Markets in the Making* (2022), Callon has also come back to highlighting the effects of competition as it is installed and governed.

the thermodynamic work of engineers and their own accounts of the social life of scientific laws I highlight this topic and position the urgent issue of how differing knowledges are given the power to count as making up the landscape of the decarbonizing society.

The social study of science necessarily includes more than the analysis of things that live in laboratories and events that take place among people with university employment contracts. The turn to 'technoscience' demonstrated this when studying the technologies and the scientific tools through which they are made and come to matter in conjunction. Not only do technologies move around, shift hands, and transform, but so do the scientific objects that are pressed together, substantiated and maintained so well that they remain scientific wherever they are stopped on their journeys. Facts are among the entities that come from somewhere: from concrete events, practices, tools, things, and the actions of living and unliving creatures (Latour, 1993, 2010). Many scholars have generatively followed in the steps of Latour and colleagues in studying scientific facts as they are made, tested, and take part in advancing networks in alliance with social movements, laboratories, devices, and policies (Haraway, 2023). But what kinds of entities are scientific laws with social lives, then? Because if facts can travel then certainly laws also have the entity form that materiality and agency provide.

To show how these concrete settings make scientific laws collide, I begin with a short background to the ethnographic site of the city of Odense, where engineers have been tasked with installing large heat pumps to decarbonize the city's public heating system, use server heat, and deliver cooling for a Facebook datacenter (requiring the practice of thermodynamics). Following Stengers' work on the history of constructivist knowledge events, I study scientific laws as mobile entities that take effect as a result of different knowledge practices. This is the backdrop to my ethnographic engagement with the scientific laws in the analysis which are unfolded through vignettes situated in teachings on thermodynamics, in a meeting of the engineers, and in the instalment of new heat pumps as mediators to serve district heating and the Facebook datacenter simultaneously.

Analyzing the three vignettes, I show how the engineers are experiencing obstruction to their pragmatic work of conserving energy for decarbonizing the district heating system. Denmark's new energy policy has enabled the installation of small heat pumps in individual buildings in prospective new connection locations for the system. This means that, suddenly, the engineers must also engage with market dynamics to make sense of the material effects of the interruption caused by the economic competition in their practice of thermodynamics. Market mechanisms are negotiable and in-the-making (Karnøe, Kirkegaard, and Caliskan, 2022), whereas molecules can be directed, conserved, and moved around (Jabloner, 2019). While the collision of these two laws highlights scientific laws as entities, it also demonstrates how their social lives differ in their material effects. Despite the governance of carbon emissions becoming an ever more crucial environmental and societal issue it is also increasingly shifting to become a project carried out by perpetrating industries' own strategies.

However, the obstruction to the engineers' work of decarbonizing public energy production and distribution provides a lesson not just in the ways energy transitions are practiced at engineering and policy levels. It equally illuminates the topic of monopoly structures, which have vastly different effects in regard to corporations and public heating systems. The contrast between the two laws – as well as how the arch enemy of competition, monopoly, is handled in the two worlds of energy and corporate governance – shows that ineffective corporate decarbonization has much to learn from the utility work of heating systems, which in Denmark have historically been collective and public. How is it possible for a utility system that is technically and societally equipped for fair, cheap decarbonization to be obstructed? The answer lies in what I describe as the collision of scientific laws.

Background: Heat pumps for district heating, dwellings, and a datacenter

New data-producing, high energy-consuming buildings, stacked with servers, are sites for construction work in both urban and rural spaces. And they are still growing in size. In the south of Odense, Denmark, next to two such server halls – both in operation, yet constructed for further extension – is a rectangular, shiny black and brown building within the new industrial quarter designed for future tech companies. Inside the

building three large heat pumps hum in ambient harmony while transforming lukewarm server air into hot water and warm radiators for the city, as well as cooling for the servers. Soon they will be accompanied by neighbors, as a similar building is being constructed as an extension to this one. More heat pumps are installed as more servers are installed.

The reason for building a container for heat pumps was the arrival in the industrial quarter of Facebook's hyperscale datacenter in 2019. Part of the planning of its construction was to connect the energy supplied by its servers to the local district heating infrastructure supplying the whole city, as the city's engineers were looking for new sources of heat in transitioning away from burning coal. The heat pumps are expected to both increase the temperature of the server air to produce hot water to be piped to heat 90,000 homes, shops, schools, the hospital, factories, and so on; and deliver its other output, cooling, to the essential cooling tubes within the datacenter. Planning for, purchasing, installing, and testing heat pumps is a costly job which is carried out by the engineers maintaining and extending the municipality-owned heating network.

This site is a network of relations between the different heat pumps, their humans, and the policies that change their environments. The engineers with whom I have done fieldwork in Odense (October and November 2020) are installing them in order to replace fossil fuels with electricity from more renewable sources and to use excess heat from the Facebook servers. Each large heat pump takes up several square meters and mostly consists of pipes moving between its components. But the affair in Odense is complicated by another element: the small heat pumps that are usually installed on the outside walls of detached family houses as substitute for fueling with gas, wood pellets, or individual oil burners.

The heating engineers in Odense also have to deal with the small heat pumps, which are now subsidized by the Danish government. Many buildings which are potential candidates for servicing by the publicly owned heating network are having the small heat pumps installed rather than choosing to rely on the major new collective heat pumps. While both types of pumps depend on electricity and the thermodynamic work

of conserving as much energy as possible, their economic and societal positioning as well as their effects are far from similar. By studying the practice of energy conservation, the material contrast of economic competition becomes comprehensible as it begins to obstruct the decarbonization project.

Constructivist knowledge, pragmatic thermodynamics, and scientific laws

Before getting to the analysis of the article, this section clarifies my reading of scientific laws, which builds on Stengers' writings on the construction of science, including her points on thermodynamics as constructivist, pragmatic practice. It suggests the importance of conflicting (in contrast to, for example, collaborating) engagements between scientific knowledge practices across disciplinary boundaries and knowledge traditions (Asdal, 2014). Particularly when the topic of investigation is not science production but 'science on the run' (Bowker, 1994). Because what happens when pragmatics meets performativity in the field? Analyzing the history of scientific disciplines, Stengers has traced constructive events in the history of physics. Reading both groundbreaking (with considerable impact) and overlooked (less read, less impact) theorists across disciplines, she argues that physics emerged as a separation between the *why's* (physical causes) and the *how's* (theoretical explanations) of worldly processes. This initial configuration is still present in a lot of physics departments. Many easily accept surrealist physics such as chaos theory, physical disorder, worm holes, and multiverses, but surprisingly still reject the point that theorists such as Poincaré and Prigogine have made part of their projects: that is, that 'the great laws of physics' are constructive conventions that can and already have been modified when solutions to contradictions are agreed upon scientifically (Stengers, 2005, p. 154). Knowledges are produced according to concrete situations in locations and history (Haraway, 1988; Pignarre and Stengers, 2011; Star, 1994), and scientific knowledges differ from others in how they are produced in terms of both principal outcomes – facts, theories, hypotheses, conversations, and laws – and secondary effects, such as certainties and generalizations (Stengers, 2011; Whitehead, 1920). Scientific truths are not stable, singularized entities but relational events (Latour, 2008). What I take from this in relation to scientific laws is that it is not possible to speak of 'knowledge in itself' but, rather, 'knowledge of' certain circumstances and contexts.

Both economics and several sub-fields of the natural sciences, like thermodynamics, electromagnetics, and microbiology, emerged from the Industrial Revolution with the development of industrial machines (Bernal, 1953; Pickering, 1997). The list of scientific intersections and transferred and borrowed concepts is long, particularly when zooming in on research conducted in the name of industrialization.[30] Daggett (2019) and Stengers (2010) trace one such scientific identification in the history of thermodynamics, which long predates formulations by the first Scottish energy scientists in the mid-1800s, who developed laws of thermodynamics as a field that rested on their pious ethic of limiting (energetic) waste. Indeed, concepts that foreshadowed energy conservation measures can be traced all the way back to the ancient Greeks, including stoic philosopher Heraclitus who argued that the cosmos was an ever-burning fire, often referred to as his philosophy of 'fire-and-flux' (Daggett, 2019).

The first law, which was later identified as the conservation of energy – energy cannot disappear because it is constant – appeared before Joule's analysis of the quantitative equivalence between heat and work in 1842 and was referred to in another manner. Stengers (2010) shows, the term 'conversion' – originally the first law of thermodynamics, later known as 'conservation' – was rejected because it mainly served an aesthetic purpose in describing the process of material translation, whereas the process of conservation enabled measurement of energy. Energy was no longer only converted from one state to another but also into a number. In other words, the conversion of energy was quantified. And the quantification of energy production for commodity production, the knowledge of how to make engines produce more with

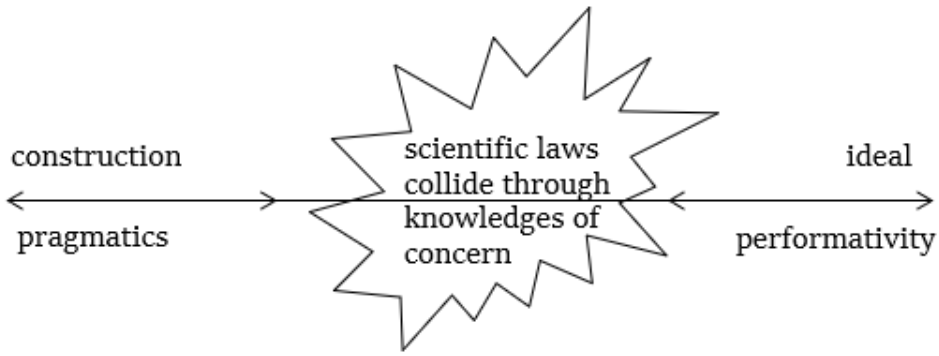
[30] The scientific concepts that were utilized in industrialization – for example, 'the economy' (which first appeared as a term in the 1930s) – were initially merely analytical descriptions; eventually, however, they came to produce their referents – to produce 'the economy', for example (Mitchell, 2005; Murphy, 2017;) – and there were many intersections during their scientific development. Thus, Schumpeter's 'scientific economics' emulated physics theory (Mirowski, 1989), and Darwin's biological evolution theory was inspired by Smith and Malthus' writings on economic competition (Gibson-Graham, 2006; Haraway, 1991). Influential sociologists like Park also adopted the 'competition' concept articulated by Darwin to explain social order as he thought it was a scientifically proven natural condition (Faught, 1986).

lower fuel expenses, proved crucial in the early days of industrialization. The quest on the part of the industrial owning classes to produce the cheapest commodities in their new factories initiated the period in which economic competition really came to impact both daily lives in the factories and town markets and also the making of energy science itself. The industrial requirement for energy quantification made the first law of thermodynamics one of conservation rather than conversion.

The consensus on the approach to scientific laws has moved from the search for a general condition of nature onto approximations. For example, Prigogine's scholarship differs from that of the positivist enlightenment project by making explicit that the point of physical laws is not to explain regularities of reality but to characterize such regularities that any concrete system may present as 'the extent to which its past determines its present and its present makes its future predictable' (Stengers, 2005, p. 155). The collective insistence on constructive possibles points out that it is not *as if* nature itself could request unveiling and show a full conformity of everything.

The differences that occur to a physical environment become documented knowledge with the study of approximations of non-symmetry between past and present (Stengers, 2010). That is why collisions are measured as events just like the emissions, compositions, and associations that make physical concrete changes to their environments – and making that measurement is part of the general scientific method. Stengers' method is to contrast performative approaches to ideal type knowledge objects, with historical instances of scientists' pushing for constructivist attention to their own practices. In my analysis of scientific laws, I build upon this foundational contrast as a stage for the collision event observed in my ethnography with the heating engineers (see figure A).

figure A: a collision event



The collision event is conceptually related to Tsing's (2004) moments of friction that interrupt universalist developmental efforts – in that collisions also occur in 'zones of awkward engagement' between groups and materials – as well as Star's (1989, 2010) 'boundary objects', which, due to their materiality, facilitate work between heterogenous (scientific) communities. Yet the collision does not primarily mediate exchange and responses as with friction, nor does it facilitate collaboration like the boundary object. Rather, when dynamics meet through forced movement, physical impact can unequally change the mass and mobility of one colliding entity more than the others – depending on how much and which forms of force a powerful body has activated. When the movement is analytically documented, not just the why and how of the collision can be analyzed but also the material effect can become a topic of critical conclusion. Collisions highlight how meetings of scientific practical differences create effects that are rarely equal. I come back to this argument on collisions in the end of the article.

Stengers insists on studying (with) scientists' own conceptualizations. Such analysis of the relations between physical environments and scientific phenomena is foundational in the social studies of science; however, it does not account for the life of such law-full forms outside of the academy – in the factory or the energy plant, for example. I take this object of scientific laws with me in order to study economic competition through energy conservation as I show that, in energy policy, competition is certainly treated as

a scientific law, and that it collides with energy conservation in doing decarbonization work.

Experiences with a collision event

1. *The constructivist science of heat pumps*

In a large meeting room within the office buildings of the district heating energy plant in Odense, Fynsværket, a course with the subtitle 'introduction to electricity using heat pumps' is about to take place. It targets the department of electricity within the local district heating organization and has been prepared and will be taught by Kai, the expert on heat pumps within the organization; Kai also conducted an industrial PhD in physics within the organization on the topic of heat pumps a couple of years ago. The department of electricity has asked for the course as they have learned that heat pumps are to be installed all around their facilities, at the energy plant and by the pipes to various places in the city, but also in many other places in Denmark and beyond. Politicians and energy analysts expect electricity will become more and more renewable due to the increasing construction of wind turbines. Kai's demonstration of the law of energy conservation shows how knowledge of energy (thermodynamics) comes about in relation to working machines and identified issues, rather than in isolation (Latour, 2008).

The members of the department of electricity sit in rows in front of the projected power point, while the heat pump expert, Kai, stands in front of the projected power point slides. The first slide argues for the advent of heat pumps with seven points (translated from Danish by the author):

> 1. Electricity-using heat pumps are a competitive alternative to the current coal boilers of the energy plant. 2. They are a politically acceptable future-oriented solution. 3. The general tax on electricity has recently been lowered. 4. The consumer tax on electric heating is being phased out. 4. There is not much financial support for biomass energy plants. 6. Biomass is not popular.

Starting with this foundation for the course is an opportunity for Kai to convince everyone in the room that heat pumps are the better alternative of several options when phasing out coal. The department receiving the course has been responsible for everything electricity-related for many years. The energy plant was first constructed to produce electricity and the heat from its turbines was used for heating local institutions, such as the city's only indoor swimming pool at the time. This was the start of district heating. As electricity in the 1990s and 2000s was increasingly produced from renewable sources, the energy plant largely came to produce district heating: coal would be burned to heat water running in circuits around the city, which proved more efficient both in terms of energy use and price levels than if every household and institution installed individual boilers.

Now, with the advent of large heat pumps, electricity is returning to the foreground, not because the energy plant produces it but because grid electricity is used to power the heat pumps, increasing the temperature of air enough to send transformed hot water into the circuit of heating pipes underlying most streets in the city. To understand heat pumps, Kai says, as he introduces the content of the course, is to understand the basics of thermodynamics. Kai's go-to description of heat pumps is that they 'work like refrigerators, just opposite', with the reminder that 'energy is always transferred from high to low temperatures.' This is the first law of thermodynamics: energy is conserved even when it is transformed into another substance. In Odense, lukewarm server air is transformed into hot water through pressure from the electricity-powered heat pumps.

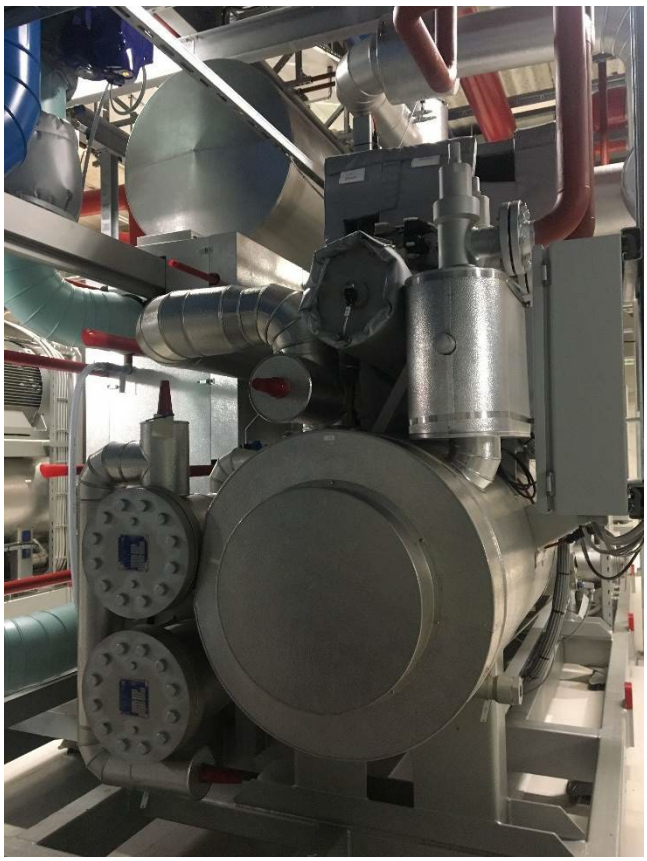


Image 1. One of the new heat pumps built to use server air from Facebook's datacenter for district heating. Photography by the author.

Commenting on his own description, Kai explains that the metaphor of the fridge makes it clear that heat pumps are about relations between hot and cold, opposites, always producing or using both on different sides with some kind of added energy – in the cases of both fridges and heat pumps: electricity. Kai's point in emphasizing the thermodynamics of both fridges and heat pumps is to highlight how energy can be transfromed through different substances, such as air and water, and be increased or decreased in temperature. It is the constructivism of energy conservation that Kai mobilizes when planning how to install more heat pumps. The utility of energy is what makes it important.

The fridge metaphor serves Kai another purpose. Just as a fridge produces heat when producing cooling – it often accumulates behind the fridge and is usually not put to use – the heat pumps also produce cooling. When I arrived in Odense to do fieldwork with the district heating engineers, one of the first things I learned (which had not become apparent in initial desk research – it was not described anywhere in the public material), was how the heat pumps also produce cooling for the servers within the datacenter. Kai is delighted with this facet of operations, and it was surprising that the

simultaneous cooling was not advertised anywhere in Facebook's wealth of material bragging about their delivery of server heat to a local heating system in Denmark.

Facebook has installed its own cooling system, Kai tells me, as it has never relied on an external cooling system before. But on an everyday basis, the heat pumps put to work by the engineers produce cooling for Facebook's servers, simultaneously ensuring the safety of Facebook data as they produce heat for the citizens of Odense. The flow of substances does not only move from Facebook to the heat pumps and into the city but also the other way around.

The law of energy conservation enables the production of value beyond organizational boundaries. Kai and his colleagues are well versed in the knowledge of how energy never disappears and can always be used somewhere for the purpose of using less fuel and reducing costs. When calculating the flows of the heat pumps and displaying them for his colleagues, Kai demonstrates that he and the heat pumps are collectively mediators of the law of energy conservation. Guided by Kai, the heat pumps create efficient energy use by being machines of energy measurement: 'the thermodynamicist is a constructivist, who recognizes that measurement "creates the object that it measures" (Stengers, 2010, p. 210; cited in Barry, 2015, p. 122). It is objectified knowledge, but what he does with it makes material and political differences. The life of this law stands in contrast to the other law with high impact in Odense as the engineers work towards making the heat for the people of Odense both as low in carbon emission and as cheap as possible. I turn to this other law in practice in the following section.

2. Competing heat pumps

People who live in areas not yet connected to district heating pipes are increasingly choosing to purchase small, single-household heat pumps to warm their homes during the cold months of the year. In Denmark that is usually October to April. They do this because these small heat pumps have been heavily subsidized in Danish energy policies from the late 2010s into the early 2020s. The small heat pumps are advertised as the best alternative to gas, oil, and wood boilers, and more and more companies specialize in installing them. For many years, district heating has expanded through the laying of pipes alongside roads in urban and suburban areas to connect increasing numbers of

buildings and therefore building managers and owners. It is the ongoing state of work and the adaptability of the infrastructure that make it valuable to local citizens (Guma, 2020), such as with new pipes and connected buildings. Every year new connections have been made and this expansion is generally considered a built-in feature of large-scale district heating: it needs to accrete to become more efficient. District heating has for decades been favored by Danes living in areas serviced by piping systems because Danish energy policy dictates that district heating cannot produce profit, stating that it must remain the cheapest energy source. Such goals are realized through energy efficiency initiatives.

Energy efficiency first became a core precept for energy production in the 1800s as a tool for industries constantly working towards cheapening the production of commodities. Worries about fuel depletion and the finite character of fuels were central to the 1860s, as stated in Jevon's famous *Coal Question* (Mirowski, 1989). It was seen as a solution to issues of price as the decreasing size of fuel repositories became particularly prominent when coal was heavily subsidized due to the oil crisis of the 1980s. How could coal be stretched further while producing the same amount of work? It was only in the 1990s that energy efficiency became a policy tool answering to heavily increasing carbon emissions and their climatic impacts (Dunlop 2022).

In heat pump language, energy efficiency is called the 'coefficient of performance.' Kai works with this measurement daily to ensure that heat pumps that are already installed and those they purchase in the future use as little electricity as possible while producing the required amount of energy for district heating. In district heating language (not just heat pumps), energy efficiency depends on the length of pipes. The longer the hot water travels the colder it will get en route, so district heating pipes are only extended when sufficient managers or owners of buildings in a prospective area all consent to connection. If a single-family houseowner on a prospective suburban street decides to purchase an individual heat pump, district heating's energy-efficiency measures might reduce the engineers' incentive to dig pipes into the area as they might have planned.

The new energy policies that heavily subsidize small heat pumps have become a major concern to the heating engineers in Odense. Private companies that sell and install heat pumps invest in marketing on a large scale, and benefit from the many economic schemes from which it becomes cheaper and faster for residents to have a small heat pump installed rather than wait for prospective district heating. In September 2020 the district heating organization formed a lobby group to respond to their concern that district heating had become 'exposed to competition', as one of the engineers told me when he invited me to one of their meetings. The core responsibility of the lobby group is to discuss options for making clear to politicians the hindrance to decreasing carbon emissions from energy: competition.

The issue considered in the meeting taking place in October 2020 is that the more people who install small heat pumps now, incentivized by climate and energy policy, the fewer the areas there will be in which to build new district heating connections. After all, the presence of a certain number of interested managers or owners in an area is necessary for a worthwhile construction project that involves hiring diggers, closing off roads, digging holes, and filling them with connected, sealed, multi-layered pipes. But most importantly, as one of the attendees observes, is that the fewer connected buildings on a new piping system, the less efficient it will become. The attendees are members of different departments of the district heating utility, discussing whether their policy work will have greater impact if responding to public hearings as usual, writing op-eds, having more conversations with the industry organization for district heating in Denmark, or writing posts on social media.

Image 2. District heating pipes for a new housing area in Odense are buried underground on a street that has been closed during the digging work. Photography by the author.

Competition has become a sedimented, collective issue for the heating engineers in Odense. Some of them are against the roll-out of small heat pumps in prospective district heating areas and others are more concerned with when, how, and through which combinations of small and large heat pumps less carbon can be emitted from energy. Kai spends some of his time at weekends calculating the emissions and prices for combining district heating and small heat pumps. His care for large-scale, electricity-system thinking displays his motivation for ensuring the planning, building, and retrofitting of the district heating system and the energy system beyond it in a way that will produce the least possible carbon emission. And this motivated skill is tested when the arrival of competition becomes a shared, stabilized concern among the heating engineers.[31]

[31] The climate and energy policies to which the engineers were reacting were those reforming district heating and suggesting individual heat pumps as a substitute for individual oil and gas boilers. Their main problem was the way in which the subsidies for individual heat pumps were treated as the first priority substitute for oil and gas, with particular effect in areas where district heating was planned or easily could extend to pipework within it. The main new policy in focus in 2020 was the new 'climate agreement for energy and industry.'

Competition has not always functioned as a law of economic activity, as I have shown here. In the guild era of the Middle Ages, for example, copying commodities and adding new traits to them was considered highly unlawful (Samuelson, 1987). The shift from liberalism to the neoliberalism of the 1900s is characterized by an understanding of human social relations that has shifted from one based on exchange to one of competition (Foucault, 2008; Read, 2009). The earlier dominating forms of liberalist theory emerging from Smith's work (1982 [1776]) in the 1700s, and the neoliberalism of the 1900s shares the definition of the political sphere as inherently economic, which explains why neoliberal policy is foundationally economic.

The transformation from the exchange relations of medieval societies to competitive relations with the coming of neoliberalism marks a defining shift for competition because it is no longer simply considered a dynamic but a law that needs protection from monopolization by both governments and large corporations. The law of competition is no longer only Darwin's explanation for all species' behavior but, rather, a governed law that produces an optimal economic state. In economic theory, competition is no longer a descriptive term for a market dynamic but the ultimate tool for 'perfect competition' in which market dynamics are valued as fair because all capital, sellers, buyers, and laborers can compete with each other (Shaikh, 2016). Important to note is that perfect competition is an ideal of economic governance rather than the opposite of governance (Fourcade, 2006; Jessop, 2015; Kjær, 2015). The arrival of competition collided with the efforts to conserve energy made by the engineers and their machines. But where does it come from?

Scientific laws, including competition, do not come about in the vacuum of academia. Economic competition became an object of consensus due to its active potential for industrial production in the 1700s. In many states, however, competition became not only semi-stabilized as a law of science but additionally a law of regulation in the first part of the 1900s. 'The law's purpose is to advance efficient societal use of resources through effective competition for the benefit of companies and consumers' (Danish Ministry of Industry, Business and Financial Affairs, 2021). These words comprise §1 in the Danish legislative text that guides what is called 'the competition law' (in other legal

frameworks also known as 'antitrust law'). It was first passed in 1931 with the purpose of hindering monopolization and then reformulated in 1990 to advance competition.

This shift is important because it marks an event in the material purpose of the law: its transition from descriptive to ideal. Another actor in Odense's net of energy flows is embedded in the effects of this event, illustrated by the lukewarm temperature of server air. The object of competition in Odense is not steered actively into collision by the economists who work with competition as law on a daily basis, but by policy and the industries that are subsidized by policy. Along its journey from academia to everyday commercial encounters, the stages and the plays in which competition plays an active part can be redefined and claimed for a variety of purposes by different powerful actors. In this study these are represented by corporations such as Facebook and other new businesses that are subsidized to produce, deliver, and install technologies for a decarbonizing society that is reliant on heat pumps – as the following section shows.

3. Lukewarm server air and the monopoly roadblock

The idealization of competition inherent in its use as a tool is not only apparent in energy policy but also in the workings of Facebook. A profile of the localized conditions from which Facebook benefits in Odense demonstrates how explicit competition-based strategy works to situate Facebook in the decarbonization plans of the engineers; however, it requires considerable work by the engineers and their machines.

The heat pumps for Facebook's server air were first tested at the start of the district heating season in 2020, when people began to turn the knobs of thermostats in workplaces and in their homes. As noted above, the district heating organization has constructed a building to house the new heat pumps adjacent to the datacenter, and Jens, who was responsible for the project, updated me on its status while introducing the newly installed machines.

The building is split in three: a visitors' room facing the datacenter, a small office with computers monitoring the heat pumps, and the humming heat-pump heart of the building where pipes cross each other and move in different directions in and out of the building. Although the components of these three large heat pumps do exactly the same

as the small heat pumps that many people are installing in their homes, they look nothing alike. These are not independent machines that one can purchase, screw on a wall, and plug in.

Image 3 and 4. Pipes carrying air and water that connect the district heating heat pumps with the Facebook datacenter. Photographies by the author.

Jens explained that the pink and blue pipes hold the air coming in and out of the Facebook datacenter (Image 3), while the red pipes contain water circulating through the district heating (Image 4). Next to each other sit three large torpedo-shaped tanks. I remember these from the course on heat pumps with Kai: the compressors. This part of the machine is powered by an electric motor that forces vapor of lower pressure and temperature to rise in temperature and pressure. Here, the server air is lukewarm 27°C but is transformed into 70°C water by the heat pumps. The water from the city pipes is 40°C when entering the heat pumps but 70°C on its return to the city, while the cooling element – 15°C air – travels back to the datacenter to cool its servers.

As we leave the noisy room with the heat pumps, Jens comments that they are powered by the same electricity as the datacenter: Facebook has included the heat pumps in the purchase agreements for the operation of everything inside the datacenter, including

the power-hungry servers. A poster in the visitor room claims that the Facebook datacenter only uses 100% renewable energy from Norwegian wind turbines; however, anyone familiar with the workings of regional energy grids knows that any major, constant electricity consumer depends on other forms of fuel, usually also fossil fuels, as backup for when the wind drops. Facebook's claim to renewability is possible with new forms of energy-market financial devices, Corporate Power Purchase Agreements (CPPAs), are increasingly being normalized by high-energy consuming industries that have the capital it takes to make large, renewable, energy construction investments (AUTHOR Forthcoming). That form of capital is reserved for state institutions, pension funds, and vast corporations like Facebook. The analysis of such tech-producing corporations, often steered by insights into competition and its economic governance arch enemy, monopoly, can be greatly informed by how monopoly and competition is handled in the governance of energy production.

Tech corporations make their capital on the products they absorb and outcompete rather than their own manufacturing. Small-scale actors in the tech industry – as well as providing the source code for almost all other services and apps than those directly owned by Big Tech – are the core material for the generation of value for the largest of the corporations (Blanke and Pybus, 2020). The dual dynamic works, not in contradiction, but by the co-existence and co-dependence of monopoly: the centralization of sellers, monopsony: the centralization of buyers (Giblin and Doctorow, 2022), and hypercompetition (Narayan, 2023). Subscribing to intentional monopolization as a business strategy was what gave Facebook its success in extending its social network and material impact so widely (Balzam and Yuran, 2022). As tech entrepreneur and venture capitalist Peter Thiel famously said at a Stanford University lecture in 2014: 'competition is for losers.' Competition in hyper-form, as a short initial business phase before monopoly and monopsony (the ability to rapidly outcompete in order to absorb), is a tech company's tool for market dominance. Even though this is a well-documented point in the literature on Big Tech and their business strategies, it is striking that politicians both in the US and in the EU argue on the topic of which regulation tools will prove most efficient in balancing competition as tool against monopolization: for example, through forms of antitrust and merger regulation.

Tech monopoly and the capital that comes with such a societal position is an effect of competition as a governed law – that is governable at all because the scientific law of competition is performative. In this case it affords market action equally in tech markets and in energy markets. But not all organizations identified as monopolies maintain themselves through competition. As Callon points out (2022), there is considerable distance from street market dynamics to capitalism, including digital capitalism, which is a point he insists on in order to show that such markets non-capitalist have existed, do exist, and that many more of such market forms could emerge under the right political conditions. In order to attune to the *concreteness* of competition relations, it is necessary to progress in the study of the law of competition as it is instrumentalized (Pignarre and Stengers, 2011).

Energy utilities in Denmark are embedded in a history of collective ownership. The cooperative movement of the 1800s formed organizations based around agriculture, energy, and grocery shopping (today, however, they have become powerful and highly profitable organizations like Arla, Danish Crown, COOP, and Andel Energi), and soon municipalities also started to build large-scale infrastructures collectively owned through the local budget. This ideology of collective and local ownership for consumers informed the support for constructing collective heating systems for citizens. In Denmark, district heating is regulated through (what in direct translation from Danish is called) a 'rest-in-itself-principle.'[32] An organization regulated on this principle cannot legally produce profits or deficits, which must be reflected in all heat prices. This is in contrast to both the smaller and major cooperatives in Denmark that are not regulated on the basis of profit. The price for heating one's apartment, school, or shoe shop is determined by only the necessary costs of producing and delivering the heat. It is a form of non-profit model that was first implemented in 1979 in the first policy on heating utilities. It was implemented in response to concerns with the formation of a 'natural monopoly' and the opportunity offered to utilities to raise prices if they were in a

[32] The principle is theoretically close to so-called cost-plus regulation which was the most common form of monopoly regulation in, for example, the US until neoliberal regulation schemes arrived in the 1980s (Olsen and Smidt, 2012).

monopoly situation (Olsen and Smidt, 2012): in other words, not to balance and enforce competition but with concern for equal, cheap access through material exchanges rather than competition.

Paradoxically, regulation by the no-profit-or-deficit principle depends on the acceptance of a natural monopoly. After many decades in effect, several Danish politicians in the 2010s campaigned against the 'resting principle' for district heating. They argued that the lack of competition limited possibilities for economic efficiency and innovation, much like other contemporary claims in the globalized wave of pushes for privatization as a driver of economic efficiency and freedom. The economic conceptualization of district heating as a natural monopoly – similar to other water and energy utility-delivering infrastructures – had, by definition, included the desire to protect the infrastructure as both critical and of public interest, as well as framing its economic form in relation to other economic forms in the capitalist welfare society. District heating is highly localized. Its core infrastructure is pipes containing hot water, meaning that sometimes even short extensions of pipework make the temperature of the water so susceptible to cool-down that an extension makes no sense at all. If district heating is a global infrastructure in any way, it is because knowledge travels publicly of how to promote, build, manage, and regulate the development of this infrastructure, but the pipework stays in the city or town for which it is built.

In other words, it is in economic terms a natural monopoly not because it has achieved, outcompeted, or strategized to become so, but because it is literally the only organization that can, by its passionate and pragmatic practice of energy conservation (thermodynamics), offer the cheapest source of ensuring sufficiently heated buildings for the built architecture and people living in the landscape in which its pipework sits. It is here that it can be claimed to have a monopoly – although, obviously, only if enough prospective local citizens actually get connected before they purchase subsidized, individual heat pumps.

What is offered by this contrast between the concreteness of the monopoly of district heating and that of Facebook is the insight that the law of competition does not define all forms of economically dependent action. How should those concrete situations and

infrastructures that decarbonize as their main prioritized work form be viewed? As it is, an effect of the collision between the performance of economic competition and the pragmatic work of energy conservation is the political neglect of district heating. I suggest an interest in the 'monopoly of/to' (the concrete construction of monopoly) is more analytically helpful than the mere categorization of organizations as monopolies or not. For example, consider the difference between statements of 'the district heating monopoly' and 'the monopoly on delivering the cheapest, most transparent and low-emitting source of heating equally for all who want it in the area of Odense, Denmark.'

Monopoly is a multiple term that spans modes of the-winner-takes-it-all to collective distribution. This roadblock of monopolization as a universally identical economic problem hinders the access, view into, and study of the plurality of the effects of the law of competition, such as hypercompetition as a business tool and perfect competition as policy tool for privatization. It is not insignificant that the neoliberally evolved version of the welfare state is often referred to as 'the competition state' (Pedersen, 2013; Voldsgaard, Mazzacuto, and Conway, 2022) – one that both ensures competition as an end but also governs through competition as means for economically sustaining the welfare state. It also shows that it is not simply the monopoly status of tech corporations that is the problem, with the power of tech corporations as framed in work to strengthen capitalist market mechanisms such as antitrust policy and limiting data surveillance (Birch, 2020, 2023). The problem is, rather, that the intensive instrumentalization of hypercompetition – with small businesses and social services alike – is not just allowed but supported by policies, by market mechanisms rather than social reform, that enable market dynamics to be surpassed quickly enough to build extremely profitable monopolies for the very few.

Colliding Scientific Laws and Car Crash Energy Policy

Why does competition between energy system actors govern the thermodynamic work of decreasing carbon emissions from the energy use on which so many people's everyday activities today depend? The neoliberal, overarching, multi-policy-embedded governance through the law of competition subscribes to the following: achieving *perfect competition* (the most idealized version of competition) is possible for any singular institution. Yet all the while tech corporations get to utilize the fact that most

governments are rolling out policies that depend on this performance for both tech regulation and for decarbonization. As with the tech sector, studies have also shown that small, new (and more emission-reduction ambitious) energy companies are struggling with the dominance of increasingly large energy monopolies (Rohracher, 2010). And the more that former, publicly owned energy utilities become privatized for the production of profit, the more they are expected to utilize for infrastructure operations an idealized form of competition.

The case for district heating and for electricity is different because, firstly, district heating is more locally dependent and does not travel as well and as far as electricity does. But it is also because electricity generation in Denmark, for example, has been subject to much more policy-based market design, privatization, and other forms of economic intervention based on perfect competition – governance designed with the hopes of producing an ideal market. Energy policy that enables privatization is not in opposition to energy policy; rather, it is created by public governance of prices, security, and quality (Silvast, 2017). In other words, in the world of perfect competition, what the regulation of industrial digitalization and of energy transitions have in common is that while both attract considerable policy interest (it is not that they are neglected as relevant sectors), energy and industrial policy assigns to those industries claiming to pioneer these areas the societal responsibility to also drive them.

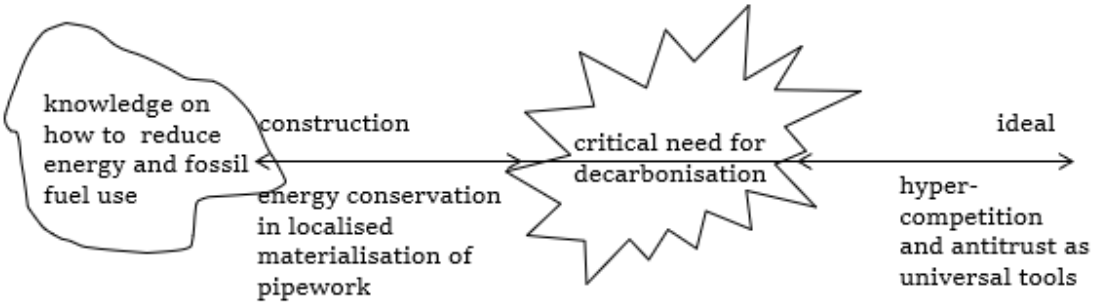
What is the problem with competition? This analysis suggests that it is the competitive form in economy-grounded policy, where it is treated as neutral (in remaking society through policy) but depends on performance. Who continues to whisper into the ears of societal planners, civil servants, and politicians that competition is a force that with the right market mechanisms will work on its own, magically making industries solve the issues of society for society whilst having to prioritize the bottom line? That competition is a natural, independent dynamic whilst monopoly is a socially dangerous dynamic?

A car crash is a form of collision. A car collides with another car, or it collides with another entity. It mostly has some consequences and rarely do all participants in the event suffer equal damages. The more solid the bodywork of a car, the more costly it is.

Having the financial power to purchase a heavy SUV certainly warrants better protection from such collisions. In this setting, the forces of energy conservation and economic competition create the crash between the little, cheap vehicle of collective distribution and the combat performance of a SUV cybertruck: the companies, big and small, which are subsidized by the governance of market mechanisms to deliver their own version of minimal corporate decarbonization.

Allowing for ambiguity of this kind, however, requires that attention be paid to how, when, where, and why they collide, and most importantly, the power relations that guide the outcome of such collisions. The challenge is not only to detect such events, such as with the small and large heat pumps, district heating and tech corporations, that these travelling and shapeshifting scientifically grounded entities such as economic competition and energy conservation collide. But also to unravel which force and the potential damage impact and location after scattering of collision of laws. The impact condition of energy conservation is in a critical state partly because the thermodynamic work of limiting carbon emissions from everyday life is constantly interrupted by new challenges. These take a wide range of forms. Not only are businesses subsidized to offer the same services, they are also subjected to top-down requirements to marketize and acquire sales and lobby skills, as well as expectations that they will deliver services to heavy energy-consuming industries with lucrative, complicated business models. Furthermore, energy and climate policy frequently depend on their not only having to radically decarbonize public infrastructure that supports everyday life but also, simultaneously, to decarbonize new, exponentially growing, hypercompetitive industries that will not reduce their energy consumption unless forced to do so (see figure B).

figure B: a concrete study of 'monopoly of/to' in the situation of small and large heat pumps in Denmark



Assembling climate change as the societal problem that it is requires radical interdisciplinarity and the pluralization of expert modes of observing – even colliding modes (Schubert, 2021). Industrial scientific laws emerged in unison but in the making of distinct scientific fields have been increasingly moved into separate territories, particularly as they have different effects depending on the situation in which they are applied. However, no empirical scientific consensus exists on whether competition stimulates or paralyzes innovation (Callon, 2022). It is interesting, then, how and why competition has become so naturalized that it is treated as resembling a physical law. Whereas extensions of knowledge coming into new terrains often is a a result of the purification and stabilization of scientific findings Strathern, 1996; Latour, 1991), such as economic competition, networks can also become enlarged through the application of a level of flexibility that only an idealized concept with no wires, handles, or manuals can offer. The flexibility pertains to the enemy against which the law promises to work and thereby also constructs: whereas for energy conservation, that is the practical waste of energy, for economic competition it is totalitarian economic power (Read, 2009). As Stengers' reading of Whitehead reminds us, the question of when knowledges are knowledges, is also a question of 'what we want from our knowledge' (2005, p. 157). The problem with the collision of the two scientific laws is that it is difficult to comprehend what is wanted from the performance of economic competition as a form of negotiable knowledge (only how and why it is done); on the other hand, the

pragmatics of energy conservation is rather more banal in that it merely directs molecules to waste less and the endeavors to ensure that less fuel is burned for the same amount of engine work.

Conclusion

I have attended here to what I refer to as a collision event in order to study the economic competition generated by energy conservation. The engineers whom I have followed ethnographically in Odense experience competition to collide with their practice of energy conservation – primarily experienced as a collision because such events are new to the world of district heating. Competition has never been necessary for ensuring cheap heat or for planning the decarbonization of heating. Yet it is also experienced as a collision because having to deal with the arrival of competition interrupts their (policy-enforced and personal ambitions for) decarbonization. The two laws collide because the engineers work pragmatically with the law of energy conservation to limit fuel consumption and decrease carbon emissions from the local heating system, whilst the balancing effects of the law of economic competition are implemented as naturally given by the policies and industry of emissions and energy. Competition as a condition that is expected to naturally balance economic and social relations moves from economics to policy and to industries that are tasked with producing and installing technologies for a decarbonizing society. But the engineers' own knowledge of how energy conservation and decarbonization works in practice problematizes the law of competition as it is implemented in energy policy. The collision event is one that highlights both the materiality and power of scientific knowledge entities.

The material forms and effects of scientific laws make them movable, as they can travel, and they can collide. It is rare that collisions result in exactly equal effects to the colliding entities, which is an opening to the investigation of how scientific laws have effect on each other in terms of critical issues and events. One of the characteristics of the laws (the one I have investigated) that can change when they move and get molded for different settings and purposes, is their work form: in other words, the question of what knowledge is *for* in a concrete situation. In the analyzed event, the entities of the two scientific laws collided because these forms were so different. Economic

competition arrived as negotiable performance and energy conservation was practiced pragmatically.

The material effect of the collision event between economic competition and energy conservation is an interruption that has slowed down decarbonization work. When the engineers must discuss and plan how to ensure individual heat pumps are not installed in areas in which they have already begun to expand district heating, they have less time to plan, calculate, and discuss how to phase out fossil fuels, decrease energy consumption, and install and use renewable energy sources. And when major tech corporations are only politicized by concern on their market impacts, their environmental impact passes as a problem that will be solved by the companies own, limited, more-financial-than-electrifying, energy market initiatives.

Coda

Speculation

Caroline Anna Salling

Book chapter in press. *Reclaiming Technology: A Poetic Scientific Vocabulary*, edited by James Maguire and Brit Ross Winthereik. Copenhagen: Ctrl+Alt+Delete Books.

Crooked worlds require crooked methods. As a technique and approach speculation is concerned with accepting that explanation is not enough on its own, and that proof and evidence are not always sufficient when working on complex matters. Contemporary worldly troubles urge an engaged practice of articulating the unusual. Practicing this approach is to "stay with the trouble" (Haraway 2016) in order to foreground what is actually going on, beyond promises of modernist progress.

Such worldly troubles encompass a vast range of technological issues and speculations, as techniques are no less critical here than elsewhere. Whether optimizing or smartifying, the extensive privileging of technological solutionism requires new forms of thinking and method. As such, it is important not only to decode but also alternatively code, uncode, reclaim, and resist technologically solutionist worlds that are designed and marketized to benefit the few.

To Alfred N. Whitehead (1978 [1929]), speculation is a project of articulating a method that can produce important knowledge. Here, *importance* is a relevant cue. As Isabelle Stengers and Didier Debaise (2017) put it, ethics is the center of speculation. It is concerned with the relation between the world and the way we act in the world, as well as the capacity to be responsible for actions and ideas that always have consequences. To speculate is to pay attention to these different paths, and the way that different actions can add extra force in the realization of such paths, by asking: How are these paths contested? What other paths are (being made) possible? How might x come to matter for y through action z? How might we/I/they, make sure z is accounted for?

Taking acts and agency seriously also brings about a certain way of relating to futures. In a speculative mode, the concept of future only becomes real when actualized, as opposed to something that can be endlessly predicted. The path going from the now is not linear, consistent, or chronological. Stories other than those narrated in a past-present-future continuum are of interest in speculative work.

This work is methodologically accomplished by paying attention to how futures are made, as well as the technologies and calculative rationalities that make them, then reworking, challenging, or dreaming of these futures through other space-time paths. And this particular choice of attention is equally an opportunity to assess our own narrations of past, present, and future in learning how experiences are situated.

Speculation requires asking, *what is etched in stone?* in order even to ask, *what if other tools were used*? But more importantly, to insist on questioning, following, tracing, and imagining otherwise. *What if the material were not even stone, but perhaps plastic, sand, soil, air, wood, cotton, coal?*

The difficult practice of leaving behind imaginings of linear progress and growth is not an easy task, because our worlds are full of these conceptions. But there is a reward. Turning to speculation is an occasion to practice imaginings of paths other than jaded forecasts, in the hope of making actions and responsibilities coalesce.

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