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From incentives to instructions: Climate policy mechanisms on heat pumps, datacentres, district heating, and epistemic collisions hindering decarbonisation in practice

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ABSTRACT

A key mechanism of contemporary climate policy is to stimulate economic competition in technology markets to ensure more efficient energy use. But, what are the consequences of such incentive-based mechanisms for achieving decarbonisation in practice? I focus on heat pumps, both large and small, that are installed in households to replace oil and gas boilers and within district heating systems to use industries' excess heat. In this study, from Big Tech datacentres. This is to examine whether climate policy is successfully translated into practice. Based on ethnography with public utility engineers of district heating in Odense, Denmark, complemented with document analysis of policy text, I chart three epistemic arrangements in decarbonisation work with attention to energy conservation, economic competition, and infrastructural connections. The epistemic practice of energy conservation is marginalised as competition mechanisms dominate climate policy instruments. The engineers' efforts to comply and resist during infrastructural connection-making, in turn, showcase the limited mobilization of policy mechanisms that instruct decarbonisation as a contrast to policy mechanisms that try to incentivize decarbonisation. Learnings on how to best mobilise epistemic practices necessarily will have to go both ways between knowledge traditions on thermodynamics and market dynamics. Ultimately, hyperscale energy consumers such as Big Tech are configured as key agents to successful decarbonisation rather than energy conserving agents that, as utilities, are targets of climate policy. These findings challenge assumptions on whether policy mechanisms are constructed to effectively limit climate change and it suggests knowledge inclusions to increase decarbonisation via critical energy conservation efforts.

1. Introduction

In 2019, news spread that Facebook had opened its first datacentre connected to a district heating system. By using the air accumulating from servers, heating could be produced in connection with the input from data storage and analysis. This new step for industry-utility relations was presented as a sustainable win-win situation: A solution to carbon emissions from the production and distribution of district heating, historically dependent on fossil fuels, biomass, and the incineration of municipal waste, and an opportunity for Facebook to contribute to local transition efforts. The initiative was supported to the degree, that in Denmark where this new connection-making took place, new policy was formulated to include incentives for the use of industrial excess heat from datacentres specifically.

Creating successful climate policy capable of rapid decarbonisation is becoming one of the most critical tasks of contemporary societies. Effectuating this task requires decreasing emissions from all parts of society [1]. As of yet, central pillars in ensuring decreased emissions via energy-focused climate policy have been eliminating taxes on electricity in contrast to fossil fuels and implementing subsidies for installations of renewable energy and energy efficiency focused technologies, such as heat pumps [2,3]. While studies show that such incentivising mechanisms are often well received in the energy sector and by energy users [4–6], they do not alone prove effective in ensuring the ambitious levels of decarbonisation needed. Existing literature has established that implementing subsidies and similar mechanisms such as feed-in-tariffs are the main success criteria for the rapid build-out of renewable energy [7,8]. However, decarbonising societies requires levels of emissions reductions that the increased construction of renewable energy cannot handle alone [9,10].

Nonetheless, at a transnational scale, most contemporary climate policies depend on economically stimulating competition in technology

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markets to introduce more renewable energy technologies into electricity grids and increase energy efficiency. The Danish 'climate agreement on energy and industry 2020' is one such example which is at the centre of the study presented in this article. The policy was passed by the majority of parties across the spectrum of the Parliament of Denmark formulating that "Danes' heating options needs to be green", and that "Danish industries are already leaders in the development of sustainable technologies." One initiative of the agreement was to eliminate excess heat tax for district heating, so that industrial excess heat could be transferred not only via sales and purchases but via certification schemes. An energy trade organization and the Big Tech datacentre industry in Denmark had lobbied for excess heat tax elimination since the first announcements of hyperscale datacentres in Denmark [Salling and Winthereik Forthcoming]. Additionally, it introduced a new subsidy scheme for replacing individual oil and gas boilers with individual heat pumps. The two parts of the agreement, the subsidy for boiler replacement and tax elimination, ensured that heat pumps, both large and small, would be connected to energy infrastructures at major scale. As a connection point between the Northern European electricity grid, it serves both for heating individual houses and for sufficiently heating excess server air to match existing district heating systems.

Server farms and the datacentre industry is extensively growing to enable digitalization of all kinds of societal and personal everyday processes [11]. The global cloud is defined by local cultures and practical work on energy infrastructures, organisations, and policy [12–14]. The dependence of the cloud on local conditions and politics takes place to the extent that it has been referred to as 'the datacentre industrial complex' [15]. Datacentres, particularly of hyperscale size such as those constructed by Big Tech companies, depend on local systems and engineering practices with consequences of 'energy gentrification' [16]. This means that, with the increase of operations in major data centres, grid owners have to prioritise who should be connected to electricity systems. It also requires new modes of energy consumption and production, for which reason many datacentre operators and tech companies become involved in new energy projects. Yet, renewable energy production for electricity consumption by hyperscale datacentres have also caused displacement of local communities and indigenous groups [17,18]. There is another side to datacentre-energy dilemmas than that of electricity production and consumption. In locations with district heating systems that collectively supply cities and towns, hyperscale datacentres are increasingly delivering excess heat from servers. In Sweden, Finland, and France, for example, such connections transform computation traffic into a new form of energy commodity [19]. However, these emerging 'thermopolitics of data' [20] in the case of Denmark has also somewhat depoliticized server excess heat. For example, the 2020 climate policy eliminating tax on excess heat enabled datacentre operators to gift server heat rather than exchange it as a commodity. This event, the elimination of excess heat tax, folds the datacentre industry into climate policy. This raises several questions: Which role is the datacentre industry assigned to ensure societal decarbonisation? Which kinds of climate policy mechanisms on how to decarbonise are being rolled out? And with which effects are they translated into everyday engineering practice?

To address these questions, I analyse the epistemic foundations involved within the implementation of small and large heat pumps with datacentre excess heat integrations. The knowledge traditions grounding both the climate policy design and engineering practice however turn out being far from aligned. To show how these epistemic matters impact successfully realising decarbonisation in practice, I develop the term of epistemic collisions. When epistemic collisions become documented analytically, not just the *why* and *how* objects collide can be analysed but also the material effect can become a topic of critical investigation. Collisions highlight how meetings of scientific practical differences create effects that are rarely equal. In contrast to generative moments of friction and conflict [21], whereas collisions do involve moments of friction, they also produce destruction, including hinderances to processes such as decarbonisation.

To illuminate such epistemic collisions and their consequences for decarbonisation, I begin with the materials and methods of ethnographic data collection on the datacentre-district heating site in 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 datacentre. I build on philosopher of science, Isabelle Stengers', work on the history of constructivist knowledge events to conceptualise what I term epistemic collisions of particular relevance to decarbonisation work. I then analyse the empirical material and chart three epistemic arrangements of collisions in decarbonisation work with attention to energy conservation, market competition, and infrastructural connections. The new climate policy requires that the utility engineers must go beyond energy conservation work, while increasingly engage with market dynamics to make sense of the material effects of the interruption caused by the economic competition in their practice of thermodynamics. 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 within engineering and policy work. But also, how epistemic arrangements within energy work can be drawn out to assist decarbonisation more explicitly. The material conditions and components of epistemic arrangements need to be analysed to reach a better understanding of the outcomes of political decisions on the critical issue of how to slow down emissions-induced climate change. As Stengers reminds us, the question of what makes knowledge into knowledge, is also a question of "what we want from our knowledge" [[26]: p. 157].

2. Materials and methods: on heat pumps for district heating, dwellings, and a datacentre

This article is based on two months of ethnographic fieldwork in October and November 2020. The qualitative, empirical material generated and employed in the analysis are fieldnotes from participant observation, reports, law-text, and interview transcriptions with utility workers of a Danish district heating utility in the city of Odense of whom most of the interlocutors were educated engineers. The study was developed as part of a larger research project looking into the impact on welfare services and welfare infrastructures from the advent of large-scale, planned digitalization. With the focus on district heating as an exemplary infrastructure largely dependent on typical welfare state policy such as non-profitability, high taxation, and universal access, also to energy, I designed the research to investigate relations between societal digitalization accredited to infrastructure build-out such as hyperscale datacentres and in practice, contemporary infrastructure decarbonisation projects. The research site of a new Facebook datacentre and district heating in the city of Odense was selected as study site substantiating the roles and responsibilities for societal decarbonisation that the hyperscale datacentre industry are appointed via policy design. The material was finally thematised from which the three topics of energy conservation, economic competition and infrastructural connections guiding the following findings sections emerged as areas that explicate complexities and problems of realising climate policy during the digital age in practice.

Odense's district heating network is a site of relations between the different heat pumps, their humans, and the policies that change their environments. The engineers, with whom I conducted fieldwork, use the excess heat from the Facebook servers along with electricity from increasingly renewable sources to replace coal. This study is centred around two different kinds of heat pumps that the utility engineers became involved with directly and indirectly. While they work on installing large heat pumps several square meters in size, consisting of pipes moving between its components to use Facebook's server air, they are confronted with small single-household heat pumps. Individual heat pumps are usually installed on the outside walls of detached family houses as substitute for fuelling with gas, wood pellets, or individual oil burners. While both types of pumps depend on electricity and the thermodynamic work of conserving as much energy as possible, their economic and societal positioning are far from similar.

The reason for constructing a new building to house heat pumps was the arrival of Facebook's hyperscale datacentre in 2019. Part of the construction planning was to connect the energy supplied by its servers to the local district heating infrastructure supplying the whole city. This came at an opportune moment as the city's engineers were looking to transition away from burning coal and were looking for new sources of heat. The heat pumps were 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 datacentre. Planning for the purchase, installation, and testing of these heat pumps is a costly job carried out by the engineers maintaining and extending the municipality-owned, non-profitable utility company's district heating network.

3. Theoretical framework: epistemic collisions

This section conceptualises epistemic collisions by drawing on Isabelle Stengers' analysis of the history of science, including her findings on thermodynamics as constructivist, pragmatic practice. Centuries before the advent of social science, thermodynamic theorists established that objects have relation-making powers and constructive material forms [22]. 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 knowledge traditions are mobilised. 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 [23]. But which role does epistemic collisions then have for (the success of) decarbonisation?

Conflicting (in contrast to, for example, collaborating) engagements across institutionalised epistemic boundaries are common [24]. This applies equally when the topic of investigation is not science production but "science on the run" [25]. Analysing the history of scientific disciplines, Stengers has traced constructive events in the history of physics. She argues that physics emerged as a separation between the *why's* (physical causes) and the *how's* (theoretical explanations) of worldly processes. Many groupings within physics easily accept surrealist physics such as chaos theory, physical disorder, worm holes, and multiverses. Yet many surprisingly still reject the point that theorists such as Henri Poincaré and Ilya Prigogine made part of their academic projects: that is, the "great laws of physics" are constructive conventions that can and already have been modified when solutions to contradictions are agreed upon scientifically [[26]: p. 154]. Knowledges are produced according to concrete situations in locations and history [27,28], 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 [29,30]. Scientific truths are not stable, singularized entities but relational events [31]. For example, physical chemist Prigogine's scholarship differs from that of the positivist enlightenment project by making explicit, that scientific laws do not to explain regularities of reality but do 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" [[26]: p. 155]. The collective insistence on constructive possibles points out that it is not *as if* nature itself could request unveiling and show coherent all-encompassing conformity.

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 [32,33]. While inherent to the industrialisation that caused emissions-induced climate change [34], these traditions are also mobilised as central to societal decarbonisation. The list of scientific intersections across the common boundaries of these sub-disciplines' is long. Specifically when zooming in on research conducted in the name of industrialisation. For example, "the economy" (which first appeared as a term in the 1930s) – were initially merely an analytical description; eventually, however, came to produce its referents – to produce "the economy" [35]. Daggett [36] and Stengers [37] 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 thermodynamics as a field resting on their pious ethic of limiting (energetic) waste. Indeed, concepts that foreshadowed energy conservation 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" [36]. The first law of thermodynamics, which was later identified as the conservation of energy – energy cannot disappear because it is constant – appeared even before James Prescott Joule's infamous finding of the quantitative equivalence between heat and work in 1842.

Stengers [37] additionally shows how "energy conversion" was originally the first law of thermodynamics. Only later it changed with reference to "energy conservation." Conversion as a term was rejected because it mainly served an aesthetic purpose in describing the process of material translation, whereas the process of conservation enabled measuring 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 lower fuel expenses, proved crucial in the early days of industrialisation. The quest on the part of the industrial owning class to produce the cheapest commodities in their new factories initiated the period in which economic competition really came to impact daily lives both in factories and town markets as well as in the making of energy science itself. The industrial requirement for the quantification of energy made the first law of thermodynamics one of conservation rather than conversion.

Stengers' method is to contrast performative approaches and ideal type knowledge objects, with historical instances of scientists' pushing for constructivist attention to their own practices. Specifically, to study (with) scientists' own conceptualizations. The differences that occur to a physical environment become documented knowledge with the study of approximations of non-symmetry between past and present [37]. Such analysis of the relations between physical environments and scientific phenomena is foundational in social studies of science; however, it does not account for the life of such law-full forms outside of the academy – in the industrial data factory or the energy plant, for example. Epistemic collisions, as building on the theory of constructive knowledge events, happen via ideal types of knowledge traditions that while in theory easily can co-exist then eventually clash in practice. The following section shows how epistemics collide in the context of climate policy as utility engineers are tasked with implementing new decarbonisation initiatives. With findings on the three areas of energy conservation, economic competition, and infrastructural connections, the study shows how epistemic arrangements are made to guide decarbonisation and how a specific collision between mobilised market dynamics and thermodynamics alters the potential success of implemented climate policy.

4. Findings

4.1. Energy conservation: the thermodynamics of heat pumps

In a large meeting room within the office buildings of the district heating energy plant called Fynsværket, located in Odense, a course titled 'introduction to electricity using heat pumps' is about to take place. The course targets the department of electricity within the local district heating utility out of whom most have a background in electrical engineering. It has been prepared by Kai, the utility's expert on heat pumps. Kai, who conducted an industrial PhD in physics within the organization on the topic of heat pumps a couple of years ago, will also be the instructor for the course. The department of electricity has requested the course as they have learned that heat pumps will be installed at large-scale within the district heating network, including at the central energy plant. The new era of heat pumps is a result of the energy transition of electricity grids. Practitioners as well as politicians expect electricity will become increasingly renewables-based due to the ongoing construction of wind turbines connected to the Northern European grid. 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 is the best alternative when phasing out coal, also in comparison to biomass such as woodchips. The department receiving the course has been responsible for everything electricity-related at the energy plant for many years. The energy plant was first constructed to produce electricity. Eventually, the heat from its electricity generating turbines was used for heating the facilities of 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 became 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. This method proved more efficient both in terms of consumption 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 mainly electricity as before, but because grid electricity is used to power the heat pumps. This increases the temperature of air enough to send transformed hot water into the circuit of heating pipes laying underneath most streets of 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 the opposite way', and continues with a 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).

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. The thermodynamics of both fridges and heat pumps transform energy through different substances, such as air and water that are 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 datacentre. 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 sustainability material showcasing 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 utility engineers produce cooling for Facebook's servers, simultaneously ensuring the safety of Facebook's data as they produce heat for the citizens of Odense. The substance flow does not only move from Facebook to the heat pumps and into the city but also the other way around.

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

Energy conservation enables the production of energetic 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 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" [22: p. 210 cited in [[37]: p. 122]]. It is objectified knowledge, but what he does with it makes material and political differences. Kai's demonstration of energy conservation shows how energy knowledge comes about in relation to working machines and identified thermodynamic issues, rather than in isolation.

In this epistemic arrangement, the large heat pumps are mobilised to comply with both the climate policy demanding increased use of heat pumps and with their own personal ambitions to decarbonise the district heating system as much as possible. It shows how Kai is concerned with emissions effects from energy production on climate change, and his transition strategy is electrification via big heat pumps as a means to decrease emissions from heating. In fact, the utility strategized on how to implement large heat pumps years before the climate policy incentivised the increased use of excess heat from industries such as Facebook. Energy conservation has for centuries epistemically defined machinic work as theory. Yet, this material on Kai and his colleagues energy conservation work shows how utility workers are starting to employ thermodynamics more performatively as a tool. Thermodynamics was the theoretical foundation for the industrialisation of societies worldwide, yet also via Kai's work shows potential as an active ideal. Energy is always conserved but could actively be conserved even more. So far so good, yet the energy conservation taking place via installing heat pumps is not the only epistemic arrangement that defines the levels of realized decarbonisation.

4.2. Economic competition: the market dynamics of heat pumps

"The parties agree that oil and gas boilers should be phased out and replaced with heat pumps, district heating, etc. It should be more attractive to choose green heating solutions. It's important to the parties that there is a good balance between collective and individual heating options. Subsidies for district heating should be implemented in areas where district heating is socio-economically favourable. In areas where district heating has not been implemented, subsidies for heat pumps should be available." (translation from the Danish Climate Agreement for Energy and Industry, October 30, 2020)

Heat pumps are increasingly connected to district heating systems. Yet they are also increasingly installed as an alternative to district heating. 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 2020 climate policy and the roll-out of a subsidy scheme by the sub-ministerial Danish Energy Agency is the central policy initiative on small heat pumps. 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 locals, 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 favoured by Danes living in areas serviced by piping systems because Danish energy policy dictates that district heating cannot produce profit, stating it must remain the cheapest energy source. Such goals are realized through energy efficiency initiatives.

In October 2020 the utility has organised a meeting to discuss a new issue that many of its workers are concerned about. The new climate policy only just implemented subsidising small single-household heat pumps is starting to impact their work on new extensions of the district heating pipes onto more houses, shops, schools, etc. District heating has been the energy policy favourite for years and is now challenged by private companies rapidly installing heat pumps in houses in every corner of the nation-state. Several of the participants, including the customer manager of the utility, are worried that the more people who install small heat pumps, now incentivised by the climate policy passed a few months before the meeting, the fewer the areas will become 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 20 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. Eventually, the meeting takes a turn as the customer manager shows a recent post on LinkedIn of his in which he explains the problem of incentivising small single-household heat pumps over district heating.

The new climate policy has 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 utility formed a lobby group to act on 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: economic competition.

In Denmark, district heating is regulated through (what in direct translation from Danish is called) a "rest-in-itself-principle." A utility regulated by this principle cannot legally produce profits or deficits, which must be reflected in all heat prices. The no-profit utility principle contrasts 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. The principle ensures the management model originally implemented in 1979 with the first policy on heating utilities. The policy securing the principle roll-out was implemented in response to concerns with the formation of a 'natural monopoly' and the opportunity offered to utilities to raise prices if utilities were monopolising. In other words, not to balance and enforce competition but with concern for equal, cheap and energy efficient access through regulated exchanges rather than via formation of economically competitive utilities.

In heat pump language, energy efficiency is synonymous with 'coefficient of performance.' Kai works with this measurement daily to ensure that heat pumps 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. This means district heating pipes are only extended when sufficient building owners and managers in a prospective area consent to connection. Therefore, if a single-family houseowner on a prospectively connected suburban street decides to purchase an individual heat pump with competitive advantage, district heating's energy-efficiency measures might reduce the engineers' incentive to dig pipes into the area (Image 2). Yet it was only in the 1990s that energy efficiency became a policy tool answering to heavily increasing greenhouse gas emissions and their climatic impacts [38]. 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 amount of fuels were central to the 1860s, as stated in Jevon's famous *Coal Question* [39]. Energy efficiency became 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.

Competition has become a sedimented, collective issue for the heating engineers in Odense. Some of them are against the roll-out of

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. Image by the author.

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 scenarios displays his motivated application of energy conservation to ensure the planning, building, and retrofitting of the district heating system and the energy system realising decarbonisation. And this application pf thermodynamics is tested when the arrival of competition becomes a shared, stabilized concern among the heating engineers.

When juxtaposing the social science literature on market competition and energy conservation, one thing particularly distinguishes their epistemic foundation. *Competition* as an economically performative within the epistemic arrangement of market dynamics [40–42] is in marked contrast with *conservation* as an energetically pragmatic epistemic arrangement within thermodynamics [22,36,37]. Market mechanisms are negotiable and in-the-making [43], whereas molecules can be directed, conserved, and moved around [44]. Performativity and pragmatics deliberately make and unmake material worlds but with different means and ends. But who makes them perform and pragmatize, and with which consequences? In common with energy conservation, economic competition is a topic understudied by social science beyond economic theory [22]. Somewhat ironically – because, as Adam Smith invented the ideal of competition in the 1700s working like an invisible hand – most social studies have deliberately not shown competition in action [45], but instead examined idealizations of competition (for notable exceptions, see [46–48]). Yet making competition happen takes considerable bureaucratic policy work [49], and, additionally, when interlocutors identify how they are forced to organize to deal with competition, then conceptual intervention does not prove analytically sufficient. Competition is a market dynamic is not merely an invisible hand, hook, or any other tool; rather, it travels as a result of considerable force to perform the liberalised market. 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 [50].

Competition has not always defined market dynamics. In the guild era of the Middle Ages, for example, copying commodities and adding new traits to them was considered highly unlawful [51]. The shift from liberalism to the neoliberalism of the 1900s is characterized by an understanding of human social relations that shifted from one based on exchange to one of competition [52]. The earlier dominating forms of liberalist theory emerging from Adam Smith's scholarship of the 1700s, and the neoliberalism of the 1900s shares the definition of the political sphere as inherently economic, which explains why neoliberal policy is fundamentally more economic than anything else. The performative mobilization of competition made possible to consider what competition *could* do rather than only what competition as a phenomenon *is*. In most contemporary economic theories, competition is no longer a descriptive term but the ultimate tool for "perfect competition" in which market dynamics enable fair exchanges when all capital, sellers, buyers, and laborers can compete with each other [53,54]. Yet, as Callon [41] points out, there is considerable distance from street market dynamics to competitive, capitalist market dynamics, including digital capitalism, which is a point he insists on in order to show that non-capitalist markets have existed, do exist, and that many more of such market forms could emerge with enough political ambition.

Economic competition became an object of consensus due to its active potential for industrial production in the 1700s. In the context of many EuroAmerican nation-states, however, competition additionally became a regulated a law 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" [55]. These words are of §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 originally passed in 1931 to hinder monopolization. Then reformulated in 1990 to advance competition. This event is important because it marks a shift in the application of competition in society at large: its transition from descriptive to purposefully performative. The transformation from the exchange relations of medieval societies to competitive relations with neoliberalisation marks a defining shift for competition. Yet, no empirical scientific consensus exists on whether economic competition stimulates or paralyzes the innovation [41], including the forms of technological and policy innovation needed to decrease greenhouse gas emissions extensively.

This epistemic arrangement of economic competition shows us that the small single-household heat pumps are contested by the utility workers as they are concerned with how much the district heating will be exposed to new forms of economic competition. Specifically, because the district heating is regulated via the 'rest-in-itself-principle' that means the utility cannot produce profit while small heat pumps are becoming heavily subsidized due to climate policy and therefore incentivised as alternative to district heating when locals transition from oil and gas boilers. While the utility workers resist these events and their recent and future consequences to intense energy conservation decarbonisation, economic competition becomes highlighted as a way in which climate policy instrumentalises transition incentivises. Despite that, economic competition guides the climate policies incentivising transition on this study's areas of district heating, datacentres, and heat pumps in Denmark. The performativity, competition as tool rather than as fact, collides with the epistemic foundation of thermodynamics as merely facts. As the engineers' experiences and concerns show, successful decarbonisation mobilised by climate policy cannot hinge solely on incentives, such as incentives for competition between utilities. Large-scale connections, complexities and inter-dependencies between infrastructures and industries is the reason for why economic competition is not enough. Large heat pump instalment and management for district heating and server excess heat in the following section shows such inter-dependencies.

4.3. Infrastructural connections: the relational dynamics of heat pumps

The performance of competition is not only apparent in energy policy but also in the workings of the heavily energy-consuming datacentre industry. Datacentres are becoming 'infrastructural in-betweens' as nodes in bigger networks simultaneously connected and disconnected to both information and energy streams [56]. A profile of the localized conditions from which Facebook benefits in Odense demonstrates how explicit competition-based strategy works to situate Facebook in the decarbonisation plans of the engineers; however, it requires considerable work by the engineers and their machines.

Datacentres are still growing in size. These, new data-producing, high-energy consuming buildings stacked with servers, are sites for construction work in both urban and rural spaces. In the South of Odense, Denmark, next to two architecturally connected server halls that makes the datacentre – 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 as they transform lukewarm server air into hot water and warm radiators for the city. 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. The district heating utility has constructed a building to house the new heat pumps adjacent to the datacentre, 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 datacentre, a small office with computers monitoring the heat pumps, and the humming heat pumps at the heart of the building where the heat pumps 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 mobile machines that one can purchase, screw on a wall, and plug in. Jens walked around the new utility building located next to the Facebook datacentre. While the new large heat pumps were to ensure the transformation of air and water into different temperatures, it was pipes that filled most of the space. Pink and blue pipes hold the air coming in and out of the Facebook datacentre (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. These tanks were also presented in 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 enters at a lukewarm 27 °C state 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 datacentre to cool its servers (Image 5). As we leave the noisy room, Jens comments that these heat pumps are powered by the same electricity as the datacentre: Facebook has included the heat pumps in the purchase agreements for the operation of everything inside the datacentre, including the power-hungry servers.

A poster in the visitor room claims that the Facebook datacentre only uses 100 % renewable energy from Norwegian wind turbines. A diagram on the poster shows a wind turbine placed right next to and directly connected to the datacentre. New forms of energy-market financial devices make Facebook's claim to renewability possible. Corporate Power Purchase Agreements (CPPAs) are increasingly normalized by high-energy consuming industries that have the capital it takes to make large, renewable, energy construction investments [Salling Forthcoming]. Yet these agreements are termed 'virtual' by the companies selling procurement and instalment. The consumption of only renewables is the financial definition rather than the energetic: When the wind does not blow hard on the Western shores of Jutland, Denmark, and the rivers are not running heavily in Norway, the datacentre depends equally on fossil fuels as any other electricity consumer.

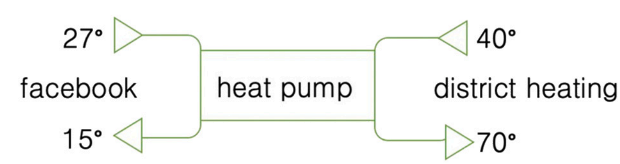

Image 5. Energy conservation between the Facebook datacentre and district heating system in Odense. Large heat pumps installed by the utility ensures that the air from servers is heated more than double the temperature to fit the district heating system's standard temperature. Diagram by the author.

Images 3 and 4. Pipes carrying air and water that connect the district heating heat pumps with the Facebook datacentre. Images by the author.

While datacentres are nodes in between major infrastructures, heat pumps also come to function as infrastructural nodes. Infrastructures ensure 'exchanges over space' [57], and they are "sunk into" other technologies, societal arrangements, organisations, including other infrastructures [58]. But energy infrastructures also require conversion and conservation machines much like the job that heat pumps is tasked with for running energy and information infrastructures successfully. In turn, the heat pumps end up showing how the heating infrastructures that Facebook delivers excess heat to, is connected to and heavily dependent on larger electricity infrastructures such as the Northern European grid. Jens is critically aware of the wider energetic connections beyond the district heating pipes, heat pumps, and servers. We talk long about how the server air is electrically serviced. Yet he ends out asserting that he feels somewhat speculative in speaking about all these things like infrastructure connections, while he at the same time is very informed about it all. He gives the reason that his job description and the success criteria of his tasks within this construction project: The heat pumps need to conserve the luke-warm server air much as possible. The epistemic complexities within this dimension of the decarbonisation project we may refer to as coming down to infrastructural connections.

Infrastructures are continuously built and extended, few left behind or abandoned. Yet the knowledge and engineering work that requires competences beyond single technological management can be referred to as of more infrastructural character. This includes knowledge on and skills in bridging sociotechnical boundaries across locations and understand how they are connected [59]. While these epistemics of infrastructural connections reaches beyond complying with or resisting incentivising mechanisms of the climate policy, they provide another important lesson for successful decarbonisation. While much less institutionalised than knowledges on thermodynamics and market dynamics, the relational dynamics between technological and societal structures such as infrastructures have similar epistemic foundations with consequences for decarbonisation practices. Yet they are learned via practices in places with concerns for how to operate infrastructures according to energy conservation. This may also be the reason why such usually informal epistemic arrangements only unfold when policy must be complied with or resisted rather than in the making of it. The Danish climate policy of 2020 is organised into initiatives that incentivize transitions in sectors and with technologies. The connections between the instalments and replacements of technologies and energy consumption levels and fuel resources are areas of infrastructural character that climate policy is yet to include in order to successfully decarbonise, for example, the datacentre industry.

5. Conclusion: instructions that put energy conservation to the front

In the Danish climate policy of 2020 on industries and energy a central topic for decarbonisation was left uncovered. Specifically, that of industrial energy consumption levels. The policy text described how to include emerging industries into energy infrastructures via incentivising the use of server excess heat from datacentres for decarbonising district heating. It also described the ambitions to build new renewable energy islands, new subsidy schemes for biogas, energy efficiency in buildings and for installing small single-household heat pumps, innovation targets in relation to technological development of Power-to-X and Carbon Capture and Storage. The void of decarbonisation initiatives beyond technology development and instalment and how to incentivize them is indicative of how emerging energy intensive industries are folded into climate policy as solution developers and collaborators rather than as targets with responsibility for compliance and efficient, crtical emissions reductions. With the analysis of how the climate policy translates into decarbonisation practices, we see how, ultimately, hyperscale energy consumers such as Big Tech are configured as key agents to successful decarbonisation rather than agents that, as utilities, are targets of climate policy.

During recent years, both small and large heat pumps are installed to increase dependence on large-scale electricity grids rather than burning fuels locally. In the city of Odense, utility engineers experience district heating infrastructure is becoming exposed to economic competition due to subsidies for small heat pumps while they are installing large heat pumps to utilise heat from industries, specifically datacentre server heat. The climate policy creates selective incentives for decarbonisation which are simultaneously received with excitement and fear by the district heating engineers. These events showcase three epistemic arrangements relevant for contemporary issues in decarbonisation work between policy and engineering practice: (1) energy conservation, (2) economic competition, and (3) infrastructural connections. By analysing these arrangements based on theorisation of 'epistemic collisions in decarbonisation practices', it becomes apparent that economic competition is stimulated via the incentivising mechanisms of climate policy. Simultaneously, the practical decarbonisation work within a Danish heating utility also shows how engineers try to mobilise energy conservation more performatively in order to actively make instalment conserving more energy. Yet the potentials of conducting decarbonisation work via conserving as much energy as possible with non-profitable utility extensions becomes limited in opposition to market dynamics hinging on competition. The form of competition stimulated via climate policy theoretically 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' knowledge of how energy conservation works in practice problematizes competition as it is implemented in energy policy made to decarbonise society overall. When the engineers must (a) plan how to ensure individual heat pumps are not installed in areas in which they have already begun to expand district heating, they have (b) less time to plan, calculate, and discuss how to phase out fossil fuels, decrease energy consumption, and install and use renewable energy sources. District heating is not a source capable of realising decarbonisation in itself but because active energy conservation work practically makes it so. And when major tech corporations are politicized by concern with only IT market impacts, computing's energetic impact passes as a problem that will be solved by IT companies limited, energy market initiatives.

In addition to the epistemic collision between energy conservation in engineering practice and economic competition in climate policy, this study identifies another epistemic arrangement with hopeful potentials for successful decarbonisation. While the public utility engineers' knowledge on how to practice the conservation of energy and to save energy most efficiently proves difficult to include into climate policy directly, their knowledge on and competencies in large-scale infrastructure complexities and dependencies proves mobilizable. This form of knowledge is informed by how heating systems depend on electricity systems and how big industries' energy consumption systems require financial energy markets mechanisms dependent on major electricity grids. The utility engineers know the new infrastructure interdependencies that growing industries construct, which is of critical importance both for understanding how greenhouse gas emissions are continued beyond externalisations by industries and how to politically undo dependencies creating new carbon lock-ins, and additionally, energy consumption lock-ins. 'Energy conservation' stands out as not only theory but also an aim with potentials for becoming an active tool in mobilising decarbonisation work within many more practices guiding decarbonisation, such as within both a variety of utilities and policy-making chambers.

Finally, the utility engineers' efforts to comply and resist climate policy, in turn, showcase the limited mobilization of policy mechanisms that instruct decarbonisation as a contrast to policy mechanisms that try to incentivize decarbonisation. This study cannot showcase to which extent subsidies for single-household heat pumps competing with district heating quantitatively interrupts work to decrease greenhouse gas emissions. Such a study requires in-depth analysis and aggregation of district heating versus electricity grid fuel sources and their emission factors. Yet it shows how contemporary climate policy mobilizes incentivising mechanisms aimed to stimulate economic competition. In turn, this finding also indicates how mechanisms that instruct how to decrease emissions from industrial energy consumption and utility energy production are insufficient. The issue with climate policy mechanisms of instructive character is that they are often perceived as limiting to individual and corporate freedom, i.e., carbon tax, consumption boundaries, rationing and allowances, fossil fuel bans, phase-outs, and blockades. A critical issue for further research is how such instructive climate policy mechanisms are framed as negative for human livelihoods. Including how climate policy debates on how to implement instructive mechanisms formulate limits to consumption and production as losses to individuals and industries as a contrast to big policy initiatives centred around redistribution mechanisms for a just and rapid transition. In conclusion, successful decarbonisation requires of climate policy to necessarily draw on and include a broader variety of knowledge bases. That means inclusion of on the ground workers and not only industry representatives specialised in policy and lobby work. Including thermodynamical and infrastructural practice-based knowledges that aim to critically conserve energy in contrast to policy in which incentives stimulating economic competition is the single guiding principle for decreasing and limiting societal carbon dioxide and other greenhouse gas emissions.

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CRediT authorship contribution statement

Caroline Anna Salling: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The author declares no potential conflict of interest.

Data availability

Data will be made available on request.

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References

[1] B.K. Sovacool, M.D. Bazilian, J. Kim, S. Griffiths, Six bold steps towards net-zero industry, Energy Res. Soc. Sci. 99 (May 2023) 103067, https://doi.org/10.1016/j.erss.2023.103067.
[2] M. Taylor, Energy subsidies: evolution in the global energy transformation to 2050, Accessed: Nov. 24, 2023. [Online]. Available:, International Renewable Energy Agency, 2020. https://www.irena.org/publications/2020/Apr/Energy-Subsidies-2020.
[3] B.K. Sovacool, Reviewing, reforming, and rethinking global energy subsidies: towards a political economy research agenda, Ecol. Econ. 135 (May 2017) 150–163, https://doi.org/10.1016/j.ecolecon.2016.12.009.
[4] C. Spandagos, M.A. Tovar Reaños, M.Á. Lynch, Public acceptance of sustainable energy innovations in the European Union: a multidimensional comparative framework for national policy, J. Clean. Prod. 340 (Mar. 2022) 130721, https://doi.org/10.1016/j.jclepro.2022.130721.
[5] N. Tryndina, et al., Renewable energy incentives on the road to sustainable development during climate change: a review, Front. Environ. Sci. 10 (2022), https://doi.org/10.3389/fenvs.2022.1016803. Accessed: Nov. 27, 2023. [Online]. Available:.
[6] G. Bölük, R. Kaplan, Effectiveness of renewable energy incentives on sustainability: evidence from dynamic panel data analysis for the EU countries and Turkey, Environ. Sci. Pollut. Res. 29 (18) (Apr. 2022) 26613–26630, https://doi.org/10.1007/s11356-021-17801-y.
[7] L. Mundaca, M. Samahita, What drives home solar PV uptake? Subsidies, peer effects and visibility in Sweden, Energy Res. Soc. Sci. 60 (Feb. 2020) 101319, https://doi.org/10.1016/j.erss.2019.101319.
[8] T. Pallesen, Valuation struggles over pricing – determining the worth of wind power, J. Cult. Econ. 9 (6) (Nov. 2016) 527–540, https://doi.org/10.1080/17530350.2016.1212084.
[9] S. Levi, Why hate carbon taxes? Machine learning evidence on the roles of personal responsibility, trust, revenue recycling, and other factors across 23 European countries, Energy Res. Soc. Sci. 73 (Mar. 2021) 101883, https://doi.org/10.1016/j.erss.2020.101883.
[10] United Nations Environment Programme, et al. [Online]. Available: https://www.unep.org/resources/emissions-gap-report-2019, 2019.
[11] M. Hogan, Facebook data storage centers as the archive’s underbelly, Telev. New Media 16 (1) (Jan. 2015) 3–18, https://doi.org/10.1177/1527476413509415.
[12] D. Pan, Storing data on the margins: making state and infrastructure in Southwest China, Inf. Commun. Soc. 25 (16) (Dec. 2022) 2412–2426, https://doi.org/10.1080/1369118X.2022.2077125.
[13] P. Brodie, Hosting cultures: placing the global data centre ‘industry’, Can. J. Commun. 46 (2) (Apr. 2021) 151–176, https://doi.org/10.22230/cjc.2021v46n2a3773.
[14] A. Vonderau, Storing data, infrastructuring the air: thermocultures of the cloud, Cult. Mach. 18 (2019).
[15] M. Hogan, The data center industrial complex, in: M. Jue, R. Ruiz (Eds.), Saturation: An Elemental Politics, Duke University Press, Durham, NC, 2021.
[16] F. Libertson, J. Velkova, J. Palm, Data-center infrastructure and energy gentrification: perspectives from Sweden, Sustain. Sci. Pract. Policy 17 (1) (Jan. 2021) 152–161, https://doi.org/10.1080/15487733.2021.1901428.
[17] B.K. Sovacool, P. Upham, C.G. Monyei, The ‘whole systems’ energy sustainability of digitalization: humanizing the community risks and benefits of Nordic datacenter development, Energy Res. Soc. Sci. 88 (Jun. 2022) 102493, https://doi.org/10.1016/j.erss.2022.102493.
[18] S. Sargsyan, Data Centers and Indigenous Sovereignty: Data Center Materialities, Representation and Power in Sápmi/Northern Sweden, Master’s Thesis, Södertörn University, 2022.
[19] J. Velkova, Data that warms: waste heat, infrastructural convergence and the computation traffic commodity, Big Data Soc. 3 (29) (2016) 1–10, https://doi.org/10.1177/2053951716684144.
[20] J. Velkova, Thermopolitics of data: cloud infrastructures and energy futures, Cult. Stud. 35 (4–5) (2021) 663–683, https://doi.org/10.1080/09502386.2021.1895243.
[21] A. Tsing, Friction: An Ethnography of Global Connection, University of Minnesota Press, Minneapolis, 2004.
[22] A. Barry, Thermodynamics, matter, politics, Distinktion J. Soc. Theory 16 (1) (Jan. 2015) 110–125, https://doi.org/10.1080/1600910X.2015.1032992.
[23] B. Latour, On the modern cult of the factish gods, in: Science and Cultural Theory, Duke University Press, Durham, NC, 2010.
[24] K. Asdal, From climate issue to oil issue: offices of public administration, versions of economics, and the ordinary technologies of politics, Environ. Plan. A 46 (9) (2014) 2110–2124, https://doi.org/10.1068/a140048p.
[25] G.C. Bowker, Science on the Run: Information Management and Industrial Geophysics at Schlumberger, 1920–1940, MIT Press, Cambridge, MA, 1994.
[26] I. Stengers, Events and histories of knowledge, Review (Fernand Braudel Center) 28 (2) (2005) 143–159.
[27] D. Haraway, Situated knowledges: the science question in feminism and the privilege of partial perspective, Fem. Stud. 14 (3) (1988) 575, https://doi.org/10.2307/3178066.
[28] S.L. Star, Misplaced concretism and concrete situations: feminism, method, and information technology, in: G.C. Bowker, S. Timmermans, A.E. Clarke, E. Balka (Eds.), Boundary Objects and Beyond: Working With Leigh Star, 2015, MIT Press, Cambridge, MA, 1994.
[29] I. Stengers, Thinking With Whitehead: A Free and Wild Creation of Concepts, Harvard University Press, Cambridge, MA, 2011.
[30] A.N. Whitehead, Concept of Nature, Cambridge University Press, Cambridge, UK, 1920.
[31] B. Latour, A textbook case revisited – knowledge as a mode of existence, in: E. J. Hackett, Michael Lynch, J. Wajcman, O. Amsterdamska (Eds.), The Handbook of Science and Technology Studies, MIT Press, Cambridge, MA, 2007, pp. 83–112.
[32] J.D. Bernal, Science, industry and society in the nineteenth century, Centaurus 3 (1) (1953) 138–165, https://doi.org/10.1111/j.1600-0498.1953.tb00526.x.
[33] M. Jacobs, The political ecology of the entropy principle: 19th century physics and the electrification of Germany, Energy Res. Soc. Sci. 98 (Apr. 2023) 103008, https://doi.org/10.1016/j.erss.2023.103008.
[34] J. Rockström, et al., A safe operating space for humanity, Nature 461 (7263) (Sep. 2009) 7263, https://doi.org/10.1038/461472a.
[35] M. Murphy, The Economization of Life, Duke University Press, Durham, NC, 2017.
[36] C.N. Daggett, The birth of energy: fossil fuels, thermodynamics, and the politics of work, in: Elements, Duke University Press, Durham, NC, 2019.
[37] I. Stengers, Cosmopolitics I, University of Minnesota Press, Minneapolis, 2010.

[38] T. Dunlop, Energy efficiency: the evolution of a motherhood concept, Soc. Stud. Sci. 52 (5) (2022) 710–732, https://doi.org/10.1177/03063127221096171.
[39] P. Mirowski, More heat than light: economics as social physics, physics as nature's economics, in: Historical Perspectives on Modern Economics, Cambridge University Press, Cambridge, 1989, https://doi.org/10.1017/CBO9780511559990.
[40] D.A. MacKenzie, F. Muniesa, L. Siu (Eds.), Do Eonomists Make Markets? On the Performativity of Economics, Princeton University Press, Princeton, 2007.
[41] M. Callon (Ed.), Laws of the Markets, Wiley-Blackwell, Oxford; Malden, MA, 1998.
[42] K. Polanyi, The Great Transformation: The Political and Economical Origins of Our Time, Beacon Press, Boston, 2001.
[43] P. Karnøe, J.K. Kirkegaard, K. Caliskan, Introducing the lens of markets-in-the-making to transition studies: the case of the Danish wind power market agencement, Environ. Innov. Soc. Trans. 44 (Sep. 2022) 79–91, https://doi.org/10.1016/j.eist.2022.05.003.
[44] A. Jabloner, A tale of two molecular Californias, Sci. Cult. 28 (1) (Jan. 2019) 1–24, https://doi.org/10.1080/09505431.2018.1524863.
[45] T. Werron, Why do we believe in competition? A historical-sociological view of competition as an institutionalized modern imaginary, Distinktion J. Soc. Theory 16 (2) (2015) 186–210, https://doi.org/10.1080/1600910X.2015.1049190.
[46] D. Narayan, Monopolization and competition under platform capitalism: analyzing transformations in the computing industry, New Media Soc. (2023), https://doi.org/10.1177/14614448221149939.
[47] T. Zuiderent-Jerak, Competition in the wild: reconfiguring healthcare markets, Soc. Stud. Sci. 39 (5) (Oct. 2009) 765–792, https://doi.org/10.1177/0306312709104433.
[48] P. Samuelson, Innovation and competition: conflicts over intellectual property rights in new technologies, Sci. Technol. Hum. Values 12 (1) (1987) 6–21, https://doi.org/10.1177/016224398701200102.
[49] Z.U. Türem, A clock-setting institute for the market age: the politics of importing 'competition' to Turkey, Differences 22 (1) (2011) 111–145, https://doi.org/10.1215/10407391-1218265.
[50] E. Bell, C. Daggett, C. Labuski, Toward feminist energy systems: why adding women and solar panels is not enough, Energy Res. Soc. Sci. 68 (Oct. 2020) 101557, https://doi.org/10.1016/j.erss.2020.101557.
[51] J. Read, A genealogy of homo-economicus: neoliberalism and the production of subjectivity, Foucault Stud. (Feb. 2009) 25–36, https://doi.org/10.22439/fs.v0i0.2465.
[52] A. Shaikh, Capitalism: Competition, Conflict, Crises, Oxford University Press, Oxford, 2016.
[53] M. Fourcade, The construction of a global profession: the transnationalization of economics, Am. J. Sociol. 112 (1) (2006) 145–194.
[54] M. Callon, Markets in the Making: Rethinking Competition, Goods, and Innovation, Zone Books, Oxford, 2022.
[55] Ministry of Industry, Business and Financial Affairs, Bekendtgørelse af konkurrenceloven, Available:, Retsinformation, 2021. https://www.retsinformation.dk/eli/lta/2021/360.
[56] A. Johnson, Data centers as infrastructural in-betweens: expanding connections and enduring marginalities in Iceland, Am. Ethnol. 46 (1) (2019) 75–88, https://doi.org/10.1111/amet.12735.
[57] B. Larkin, The politics and poetics of infrastructure, Annu. Rev. Anthropol. 42 (1) (Oct. 2013) 327–343, https://doi.org/10.1146/annurev-anthro-092412-155522.
[58] S.L. Star, K. Ruhleder, Steps toward an ecology of infrastructure: design and access for large information spaces, Inf. Syst. Res. 7 (1) (1996) 111–134, https://doi.org/10.1287/isre.7.1.111.
[59] S. Sawyer, I. Erickson, M.H. Jarrahi, J. Vertesi, D. Ribes, Infrastructural competence, in: digitalSTS: A Field Guide for Science and Technology Studies, Princeton University Press, 2019.

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