Engaging Science, Technology, and Society

ORIGINAL RESEARCH ARTICLE

Industrial Excess: Data Storage, Energy and Utility Planning Before, During and After Digital Industrialisation

CAROLINE ANNA SALLING
UNIVERSITY OF COPENHAGEN
DENMARK

JAMES MAGUIRE
IT UNIVERSITY OF COPENHAGEN
DENMARK

Abstract

Excess is usually understood in research as the point at which materiality gets too much. This article shows instead that materiality is always already excessive. The energy utility workers in our study convey that any product making industry also makes excess. In their view, excess as an energetic form is impossible to eliminate from industrial operations. Excess can be reduced, but complete elimination is only possible if industrial operation did not exist. This concretised state of excess becomes apparent when studying the plans facilitating digital industries' expansion projects. We focus on an implemented utility infrastructure plan for connecting a 'big tech' hyperscale datacentre to a public energy system and the classification work it involves. This particular plan leads us to the analytical object of industrial excess. Despite the high impact on public infrastructures and energy consumption, utility plans and these connections with industrialisation projects have been overlooked within scholarship on the digital economy and datacentres. We call this process of connection-making *digital industrialisation*. Our ethnography with utility workers in Odense, Denmark, shows three analytical entries of boundaries, scales, and admission points into the practices of planning for, *with* and *against* excess in connecting expanding industries to publicly owned, non-profitable utility infrastructure. The utility plan shields the energy system against high pollution impacts of digital industrialisation at a municipal scale but exposes its climatic consequences at a transnational scale. The notion of industrial excess devise how forms of industrial product-making and consumptions of industrial products are infrastructurally normalized, and which are not, ultimately giving insight into the radical potential of the non-profitable utility as a figure for ecological transformation.

Keywords

industrialisation; Facebook; datacentre; energy; infrastructure; classification; district heating; excess

To cite this article: Salling, Caroline Anna, and James Maguire. 2024. "Industrial Excess: Data Storage, Energy and Utility Planning Before, During and After Digital Industrialisation." *Engaging Science, Technology, and Society* 10(3): 90–119.
https://doi.org/10.17351/ests2023.1943.

To email contact Caroline Anna Salling: csa@anthro.ku.dk.

Introduction

"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 a coal phase-out process that he managed. Niels works for the public, municipality-owned, non-profitable district heating utility, Fyn District Heating[1] in the city of Odense, in Denmark. For five years his team has been 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 everyday activities and needs. October the 1st to the 30th of April 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 data of many of the tech company's platform users. Since its opening in 2019, it has been 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). Facebook's® Prineville (the US) and Luleå (Sweden) datacentres materialized with hopes for local economic development goals and re-industrialisation (Burrell 2020; Vonderau 2019), yet in Odense the lead up to and continuous work after its opening mostly received attention from news media on the grounds of two things. (1) the energy consumption levels in the form of electricity, and (2) the connection to the local heating system. In the years leading up to the opening of the Odense datacentre, the heating engineers were busy figuring out how to use the heat from the servers for their heating system. The Danish Ministry of Foreign Affairs' investment team 'Invest in Denmark' first matched municipalities with 'big tech' corporations planning to build European datacentres. Then utility engineers at Fyn District Heating were tasked with fitting this heat into their utility's decarbonization plan. As Niels' comment exemplifies, the server heat was part of all scenarios in the plan of how to transition into phasing out fossil fuels. When meeting a few weeks after the slideshow introduction, he remained clear on the point that using the server heat was not a choice but rather a project they were assigned.

The business strategy reasons for the datacentre and heating system connection are reflected in the 2021 Meta Sustainability Report (2022). It 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

[1] In Danish, *Fjernvarme Fyn.*

our products, family of apps and knowledge to catalyze circularity in our industry and beyond. (ibid. 44)

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 2022; Carton et al. 2020). In such chains, all materials and toxins appear to be reabsorbed by the same system of which they were discarded 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 businesses have quickly jumped on the bandwagon of using such management strategies 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' (n.d.) also aims to promote material management to shape 'a new circular economy' via ecological modernization (Daniel 2022; Zhang 2020).

Industrial energy consumption materialises the majority of global carbon emissions, as in 2015 industries consumed 54.8 per cent of the global energy produced (Huber 2022). Within Denmark, datacentres in 2022 alone, consumed more than 10 per cent of all electricity produced. By analysing information from current datacentre projects, the Danish Energy Agency, a sub-ministry institution, has estimated that by 2050, datacentres alone will use more than 50 per cent of the total electricity consumed in Denmark.[2] Through 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 much too familiar colonial territorial struggles that emanate from datacentre and data collecting observatory constructions because rural areas are chosen as fitting conditions (Au 2024; Leheudé 2022; Childs 2022). Compared to other historical mega industries, however, the tech industries' globally more dispersed industrial circulation infrastructures have made it difficult for researchers to access the corporate digital industrial machine (Hogan, Edwards, and Cooper 2022; Cooper 2021; Neilson and Notley 2019). By building on these studies and attending to the complex of the datacentre as an industrial *entity*, we extend by looking into the *process* of industrialisation enabling and maintaining the industrialisation that corporate digitalisation so-far has depended upon. The existing and escalating role of digital industries for the emission of greenhouse gases gives rise to several questions:

- How is this major capacity within the energy system actualised?

[2] Data combined from two recent reports on the Danish future energy system. 14,500 GWh datacentre electricity consumption out of a total Danish electricity consumption at 26,000 GWh in 2050 (Danish Energy Agency 2022a; 2022b).

- Which systems come to be interoperated in the new infrastructure plans for digital industries and energy operators?
- And which barriers are constructed to keep the operations of the utility and the tech company separated despite new infrastructure connections beyond boundaries of public and private ownership?

To answer these questions, we study the infrastructure plan for the connection between the Odense heating system and the Facebook® datacentre. Particularly, by exploring engineers' classification practices conducted with the perspective of connecting and including digital hyperscale industrialisation into energy systems. The particular object of classification we find as central to the infrastructure plan is that of 'excess' from industries which the engineers delineate and direct. The Danish term for excess, *overskud*, refers to the material that is left over from one process and often added to another, and is in opposition to, *underskud*, a deficit situation in which a material, such as money, mental space, energy, is too little for the purpose it was intended. The scenario of planning for datacentre-heating connections makes sense to industries in Denmark given the longstanding tradition within the country of funnelling local *industrial excess heat*[3] (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. Industrial excess as well as how it is made, unmade and infrastructured provides an entry point into understanding how growing industries normalise and legitimise their material effects at both minor and major scales. By learning from the utility workers what industrial excess is and what it makes possible, we analytically work with this 'conceptual object' (Ballestero and Oyarzoun 2022) to show how digital industrialization is concretized in practice.

Until now, cultural and philosophical studies have shown excess 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 and weird material substances, subjects and thoughts (Taylor 2018; Yusoff 2009; Moore 2009; Edensor 2005; Grosz 2001; Bataille [1949] 1991; 1985). Science and technology studies (STS) has been less occupied with forms of excess, probably due to the quite normative characteristics of the term. The empirically grounded and situated commitments of STS may seem to conflict with how notions of excess devise what is too much and what is more than enough. Instead, mechanisms that devise such normalisations have been analysed by studying how 'overflows' emerge. To exemplify, in 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 terminology of sociologist of innovation, Michel Callon (1998), it overflows into the framing of markets. Take a common phrase in climate economics: externalities. Specifically, carbon emissions

[3] In Danish, *industriel overskudsvarme*.

that cannot be accounted for are positioned as 'a market failure' (Huber 2022). Yet, treating carbon emissions as an externality of industrialisation generates an environment in which emissions are the externalised outlier in an otherwise well-ordered world. Understanding how boundaries between inside and outside are made takes scholarship some way, but how do we understand why that is, and the consequences of it? Another kin to 'excess' has guided many critical theory and urban studies. Industrial production has several costs, such as fuels and salaries, but is only successful if producing a 'surplus' of capital for the industrial capitalist (Barclay and Stengell 1975). While some would say that 'surplus' closes down analysis of worldly events, others would say that 'overflow' leaves it too open. Whereas 'overflows' enable the measurement of economic boundaries installed between the internals of material production and exclusions, 'surplus' enables economic measurement between centralized material wealth and energy in relation to human labour. But they have something in common. Both are theoretical concepts developed for scholarly purposes. Surplus and overflow are concepts developed to study economic processes with material consequences. However, as we frame *excess* in this context, it is more of a material with economic consequences. With an interest in vernacular makings of insides and outsides, cuts and frames for utility purposes, we open up the making and unmaking of not only excess but industrial excess. Not to theoretically synthesise surplus and overflow but to offer a view into how excess-constructers and managers cut the world. The implication: We see how it is not material growth that is getting excessive, but that materiality is always—already excessive.

In order to apprehend this form of excess, we situate our study by introducing the site of Odense's energy plant and utility Fyn District Heating as well as the ethnographic study with engineers managing the infrastructure plan, which is our main focus. We draw on social studies of industrialisation, datacentre construction and the digital economy from which we sketch out the process we refer to as 'digital industrialisation'. Spatially and temporally – digital industrialisation transforms an area – making it economically valuable to the centralised digital industry. This focus on utility operation in the era of industrial digitalisation highlights not only how companies such as Big Tech industrialise new areas or re-industrialise other areas but, more importantly, how more or less industrial processes become connected, disconnected and with which consequences for infrastructural autonomy and decarbonisation. 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. The material shows that the infrastructure plan creates more than the reuse of server air for a heating system; it both shields against and opens up for the continued, constructed connection points between hyperscale digital industries and utility systems.

Research Site: Non-Profitable Utility Planning in Odense, Denmark

Over a two-month period (October and November 2020) the first author was accepted as an intern and researcher in Fyn District Heating. Fieldwork consisted of attending meetings, learning from employees as they made vignettes on boundaries their calculations and wrote reports, joining visits to various Fyn District Heating 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 appreciated analytical inspiration for their strategy-making on the utility's major energy plant.

The energy plant in Odense (now run by Fyn District Heating) was constructed 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 upon in Danish 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. Fyn District Heating is the case of a particular form of utility. The Odense energy plant has always delivered district heating, yet the ownership forms and economic inputs and outputs have shifted over time. The energy plant was initially municipally financed and owned. In 1956 it became shareholder owned by the energy production company Elsam (short for the electricity collaboration between the Danish regions Jylland and Fyn) that was made to centralise electricity production, after which the garbage incineration part of the plant was sold to the (then) Danish state owned DONG (short for Danish Oil and Natural Gas) which later changed into Ørsted® (now named after the Danish scientist of electromagnetism), when the company after a national Government decision became half state, half shareholder-owned by investment including from Goldman Sachs®. Then the energy plant including garbage incineration was sold off to the Swedish state-owned Vattenfall in 2006 and finally in 2015 bought by the municipality owned, non-profitable company Fyn District Heating that had until then only managed the city infrastructure and purchased excess heat from electricity production and garbage incineration from the variety of previous owners and ownership forms. As energy policy was shifting to incentivize electricity production via renewables rather than via large, central energy plants, the Odense energy plant (see figure 1 and figure 2) became of more potential value to the local district heating delivery scheme than it could have continued to be for Vattenfall. This history, though rarely presented as such, showcases a transformation quite rare in the 2010s; that of a re-municipalisation ensuring non-profitable utility operation. In more recent years the renewed focus on district heating has been given a particular climate inflection. Municipally- or cooperatively-owned district heating systems have, as such, become a central pillar within transition studies and policy (Caussarieu 2021): particularly with district heating positioned an 'energy efficient' organisational form of heating such as within EU buildings and energy regulation (Dunlop 2022).

For decades, larger cities have also been using a broad mix of fuels: gas, oil, coal, biomass, electric boilers, and garbage incineration. Including 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 storing, analysis and production of data has now been added to this list with the addition of Facebook®. Yet the industrialisation process resulting in data excess presents another, more pervasive, change for the utility as it is not only utilised but also built into its fossil fuel phase-out plan responding to the climatic consequences of greenhouse gas emissions.

Figure 1. Old section of the Odense energy plant. Source: Caroline Anna Salling, November 27, 2020.

Figure 2. The last piles of coal for district heating in Odense before it is phased out as fuel. Source: Caroline Anna Salling, November 2, 2020.

In 2015, the Fyn District Heating 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, Fyn District Heating 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 straight forward process of installing pumps to use the server air turned out to require a lot of work to make the industrial excess valuable.

Then, in December 2022, hundreds of construction workers at the Odense datacentre were laid off without severance plans due to the corporation's decision to develop more AI datacentres for the Metaverse®, instead of the more traditional backup storage facilities. However, this event is the first in which Odense's locals have expressed significant public disappointment with Facebook's® decisions on its Odense operations. The datacentre-heating system connection received very little critical or negative attention during its first years of operation. 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.

Classification Practices and Digital Industrialisation

Digital industries create the machine-heavy infrastructure that enables market exchanges through software innovation, entrepreneurship and 'the data-driven knowledge society' (Jørgensen 2021). No doubt, industries creating both hardware and software come in all kinds of sizes. Yet since the 2000s, global digitalization trends, expansions and innovations have been dominated by major US-based companies that tend to absorb smaller start-ups and international infrastructures (Birch and Bronson 2022). Scholarship on 'digital frontiers' has been inflicted with the problem of analytical findings that centre concerns and issues found in the Global North as encompassing concerns and issues found in the Global South (Cirolia et al. 2023). In addition, the consequences of digitalization on industrial operations and energy infrastructures still come to largely rely on findings from the US-based analytical perspective on US-originating digital platform companies.

The analysis of new machines as they are developed for industrial, scientific, and societal purposes has always been the core focus of STS literature showing how public, private, common, and corporate processes are interrelated rather than separate (Haraway 1997). It 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 twenty-first century (Zuboff 2022; Poon 2016). 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 instalments and interconnections.

Nevertheless, studies on Facebook® and other companies of the digital industry have revealed controversial and harmful extractive impacts on local communities and environments. Corporate hyperscale datacentre operations have been documented to bring about fewer local jobs than initially promised, enormous concentrated profit, landscape capture, and substantial water extraction (Greene 2022; Munn 2021; Bresnihan and Brodie 2021; Hogan 2018). Furthermore, despite considerable local public involvement in enabling data industrialism to arrive, and expectations of national and local economic benefits (Salling and Winthereik 2025, 1–18; Pan 2022; Maguire and Winthereik 2021; Burrell 2020; Vonderau 2019), these industries can abandon and downscale facilities so suddenly that ruination often surprises locals who were promised jobs and increased revenue via local business (Velkova 2023). Industrialisation is usually represented as rusty and clunky, the hyper-consuming backside to smart, digital urbanization (Brodie 2021; Ensmenger 2021; Johnson 2019; Levenda and Mahmoudi 2019). This infrastructural other side of interfaces, platforms, and data being made, we refer to as 'digital industrialisation' to show the societal processes in which the infrastructure plans of datacentre and utility connections are made, and in addition, make digitalization at the platform level possible.

Academic analysis of industrialisation, and particularly what environmental ethnographer Kim Fortun calls 'late industrialism' (2012, 2014), has nurtured ethnographic attention to the toxicity of deteriorating industrialist projects such as chemical plants making pesticides and polymers, in addition to, their catastrophic environmental impacts. Anti-colonial and feminist activists, along with environmental and discard studies scholars have pushed back against industries that treat the toxicities of chemical infrastructure as mere externalities. This literature emphasizes that – chemical damage is a characteristic of industrial production – rather than a rare accident to be fixed with single filters to an industrial infrastructure of pipes and chimneys (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 the processes of toxifying, leaking, wasting, polluting, and recycling as characteristics of industrial production and consumption rather than merely the effects of industrialisation. 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). In this way, we can consider how engineers categorise some outputs from energy infrastructure as problematic and others as internal to the process of infrastructure operation. Scholars of infrastructure studies, Geoffrey Bowker and Susan Leigh Star (1999), theorised classification practices by examining large-scale systems that, for practical and bureaucratic reasons, segment the world into categories (for example, medical systems that differentiate and define diseases). Yet, there are many categorical products of classification practices that not only end within large systems, infrastructures, databases, and standards, but also frame, filter and sort our encounters in everyday life. Drawing on these key STS findings on classification work, allows us to consider the work of making an infrastructural category that sits somewhere in the middle of formality and informality. The framework of classification helps us to show how engineers work with excess as critical to the success of their infrastructure plan with inputs and implications that reach far beyond technical systematisation. The same categories can eventually be utilised for planning both the *before* and *after* of digital industrialisation.

Boundaries, and the Before of Digital Industrialization

Boundaries between organizational entities are almost never set but both mouldable and negotiable (Star 2010). In a meeting at Fyn District Heating, the object of excess in heat form was diagrammed by discussing its boundaries. The engineers that are 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. The engineer stated that he had not yet found the time to read it. Another engineer eagerly commented that perhaps it would be helpful to talk about the history of the infrastructure when planning its future.

Indulging in an examination of infrastructural history is a rare luxury for the harried engineers of Fyn District Heating 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, 89; author's translation)

'That's basically how it works, even today', one of the engineers commented. Implied by the word 'basically' is a major 'almost' 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, the engineers and the ethnographer decided to get together and discuss these issues in a more workshop-like space. The workshop came to centre around 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 central heating. Back then, Niels suggested, 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, atop a stable, with lines symbolising heat moving upwards, Niels emphasized that household animals were primarily kept for milk and food. However, the animals' body heat was used to warm the home from underneath. It served as 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'. However, the funnelling of heat between infrastructures, such as in between the utility and the industrial factory, only occurred with the construction of 'industrial excess' as a material capable of being 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. Meaning that, 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 pipes to and from the energy plant and buildings.

The group participating in the workshop went on to draw a diagram of excess heat, describing the relations between an *industrial process* and the component *fuel*, *product*, and *unavoidable excess*. Kai, one of the more recently hired workers yet very informed about the history of industrial excess heat, 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 '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. The group eventually came to conclude that although the types of processes, fuels, products, and forms of excess have all changed over time, the process that the diagram describes remains the same.

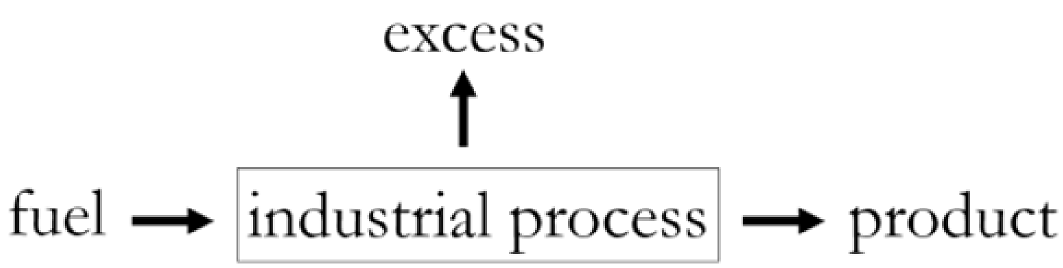

Figure 3. Diagram of how industrial excess is made. Source: reproduction by the authors.

The boundaries to the industrial process, along with its excess, which utilities are tasked with managing, are shown in figure 3. 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 Fyn District Heating to produce district heating.

One participant added that the excess of a process can be minimized through energy efficiency measures. But, it will always be there in some form, since energy cannot just disappear, in accordance with 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 Cara New Daggett (2019), scholar of energy and environmental politics, has shown, wasting energy has been the ultimate sin (in the religiously Christian sense) of energy engineering since the intellectual and industrial invention of thermodynamics. Danish politicians' agreements with Facebook® on the datacentre ensured that the engineers *had to* make the data industrial excess useful, but the thermodynamic obligation made the engineers *want to*, as they had been schooled in thermodynamics before arriving at the utility. The engineers' thermodynamic obligation to use industrial excess as a form of fuel is in stark contrast to Facebook®'s work to isolate the exemplary circularity figure from the material management of their industrial operations.

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 greenhouse gas 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*. In other words, it is *excessive enough* when it is material that would not be used, if not consumed by the district heating.

Beyond industrial excess, both logistics and supply chains also connect processes of production with processes of consumption (Rossiter 2016; Cowen 2014) and supply chains (Hockenberry 2021; 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 figure 3 exemplifies, excess is as a connecter between the processes that are not schematized by industries themselves. It serves as the missing piece between industrial production and energy consumption, enabling the relations between perform circularity adequately.

Scales, and the Course of Digital Industrialization

Thermal management is a highly cultural issue, especially within the history of media technologies, such as the internet (Starosielski 2022). But also, an economic dimension comes into play when, using, reusing, and discarding materials, particularly those with qualities measured in temperature. 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 (Pfotenhauer et 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. The following illustrates through Niels' engagements with the electrification plan from Fyn District Heating these scales, blending together environmental effects from server air transformation altogether with electricity production and consumption making the district heating-datacentre connection possible at all.

Large trucks that deliver garbage to Fyn District Heating's incineration area rumbled by outside as Niels talks about the end of the coal era in Odense. He points to the storage area which was recently filled with coal for the last time as part of the transition plan in which the infrastructure connection plan is one element. Facebook's® server heat is, according to Niels, a cornerstone in the new renewable electricity path for Fyn District Heating. The plan for phasing out coal, Niels smiles as he informs the first author, 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 in recent years he has with determination worked towards a scenario that is almost solely dependent on electricity. 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 that the energy plant historically produced. 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. 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 to produce heating, the excess from Facebook® is seen as key to driving the local coal phase-out.

Facebook's® datacentre in Odense as well as the heat pumps transforming server air into district heating 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 per cent renewable energy (Meta 2022). In Odense, this claim is achieved through the construction of a wind turbine park in Norway. The Facebook® communications manager for the Nordic region has stated that the project, funded by Facebook® itself, works to compensate the Nordic electricity grid for the datacentre's electricity consumption (Energy Supply 2019).

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 Fyn District Heating, and Facebook® took place at the end of the 2010s, electricity prices were at a record low due to the increasing integration of wind energy. In policy terms, electrification of the overall energy system, particularly heating systems, was the key decarbonization instrument and, therefore, part of Fyn District Heating's transition plan. Electricity also takes centre stage in much of Facebook's®

promotional material. In an image published on Facebook's® sustainability website, a wind turbine towers over the datacentre, neatly plugging into and powering its operations. In a visitor room at the utility's new building next to Facebook's® datacentre, a poster displays the same image. When visiting the facilities, Jens, the manager of connecting the datacentre and heating system pipes, explained how the electricity supply to Facebook® is a much more complicated matter than is represented in the image used in the sustainability report. Looking beyond the neatness of Facebook's® own brochures, the Nordic grid infrastructure that electrifies the datacentre tells another story.

EuroAmerican 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. For its Northern European datacentre operations, the Facebook® corporation has invested in wind turbines built in southwest Norway through Luxcara®, a German company specialized in asset management (Judge 2018). 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 affords the Facebook® corporation certainty that the datacentre electricity prices will remain stable during its active years. The megawatts 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 tool for abating carbon emissions (Kobus, Nasrallah, and Guidera 2021; Pasek 2019). 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 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 consumed is not always 100 per cent renewable, the electricity is financially, and therefore also legally, still considered to emit less carbon than burning coal 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 is an energy markets tool, not an energy systems tool. If Facebook® had purchased wind turbines without PPAs the claim to '100 per cent renewables' would not have been possible, as the datacentre is materially dependent on all the other fuels burned in supplying the regional grid. Additionally, as one of the engineers from Fyn District Heating 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, with the construction of wind turbines in the same place without the PPA as the compensational instalment for the hyperscale electricity consumption of the hyperscale datacentre, another institution could have purchased the rights to the territory and produced electricity for the grid. Due to the increasing recognition of the necessity for more renewable energy construction by Nordic parliaments, as well as numerous local institutions and social groups, any available zoned and procured land for renewable energy construction is utilised.

The accumulation of electrons from harnessed wind was a major argument for electrifying all energy processes when the first author (Salling) in 2020 was doing fieldwork in Odense. But two years later, during the energy crisis of 2022, the case for electrification had completely changed as energy prices skyrocketed. This was a major cause of concern for Fyn District Heating 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 for the same price as negotiated from initial operation in 2019 due to the PPA, energy poverty as effect of the heavy increase in fuel prices suddenly became a public issue in the otherwise for decades fairly energy affordable Nordic countries.

Deliberate scale-mismatching is common company practice in realising industrialising ambitions (Liboiron and Lepawsky 2022). It presents infrastructural solutions as solving issues at more scales than is the case. Given the designed appearance that Facebook's® energy consumption is somewhat equivalent to its financially-supported wind turbine energy generation, the transfer of server air as excess is left as an extra offsetting, sustainable deed of the Facebook® corporation. Yet the excess heat of server air – which 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 per cent of total electricity consumption of the country with around 5,900,000 inhabitants. The effects are far beyond comparison as well as compensation. The evasiveness that comes with the scale of hyper, enormous, distributed datacentres, and all that they depend on, is managed as an industrial advantage.

In legal terms, the datacentre has been decarbonized, but when attending to the wires and cables of the grid, the transformation process tells instead the story of a new amount of energy consumed meanwhile new wind turbines have been constructed. 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 investment advantage in energy markets is an organizational arrangement that affords this deliberate infrastructuring of different scales.

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. 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. Utilities such as electricity companies and district heating systems are infrastructures utilised for many purposes including 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). Data, just like the traffic of drugs, break the frame of the nation-state as the only sensible container for analysis on the politics of technological transformation (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 territorially-made borders makes it possible to examine the power tools of these industries, of which much policy is simply made to enhance.

As Niels and his colleagues made explicit, the financial, and technical infrastructures, including anything that is part of the infrastructure, are rarely the same. 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 entry point into industrial excess shows how scaling practices open the local energy system in Odense to ongoing digital industrialisation—while transnationally the differences in scale of energy exchanges are exposed. Industrial excess handling is not excess limited, but excess used, re-used, furthered into an accumulation chain of operations, but only with assistance from existing, non-profitable forms of engineered handling.

Admissions, and the After of Digital Industrialization

The politics of containment is a character trait of digital industrialisation, where 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 facilitating the digital economy? And how dependent does the heating system and supply of heat for Odense's residents, visitors and workers become on the digitalising industry? Whereas utility workers engineer vents, datacentres have walls. Jens, another of Fyn District Heating's engineer utility workers, demonstrated the contrast between admission to the spaces of data production and energy production as the following shows.

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 utility's network that houses heat pumps for the consuming and transforming of Facebook's® server air. Heat pumps elevate the temperature of the server air through electricity as the server air in itself is not warm enough for the network. In that sense, the server air is not actually useful industrial excess until the utility has not only consumed it but also 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 (see figure 4) (Salling 2024).

The utility's new 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.

Figure 4. The wall of the Facebook® datacentre in Odense. Source: Caroline Anna Salling, September 15, 2022.

While sitting 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 building 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 annex 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 was constructed. According to Jens, server 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 Fyn District Heating'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 policy delegations are common visitors in both the central and new facilities.

Figure 5. Plastic tubes on display in the new building representing the various fuels used for the district heating. Source: Caroline Anna Salling, October 27, 2020.

Next to the entrance door is a display unit with six plastic tubes, each containing a fuel source that is currently utilized at the energy plant. Sweeping his hand from left to right (see figure 5), Jens lists: 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 Fyn District Heating's own turbines – cannot be represented but is still too materially important to energy production at Fyn District Heating 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.

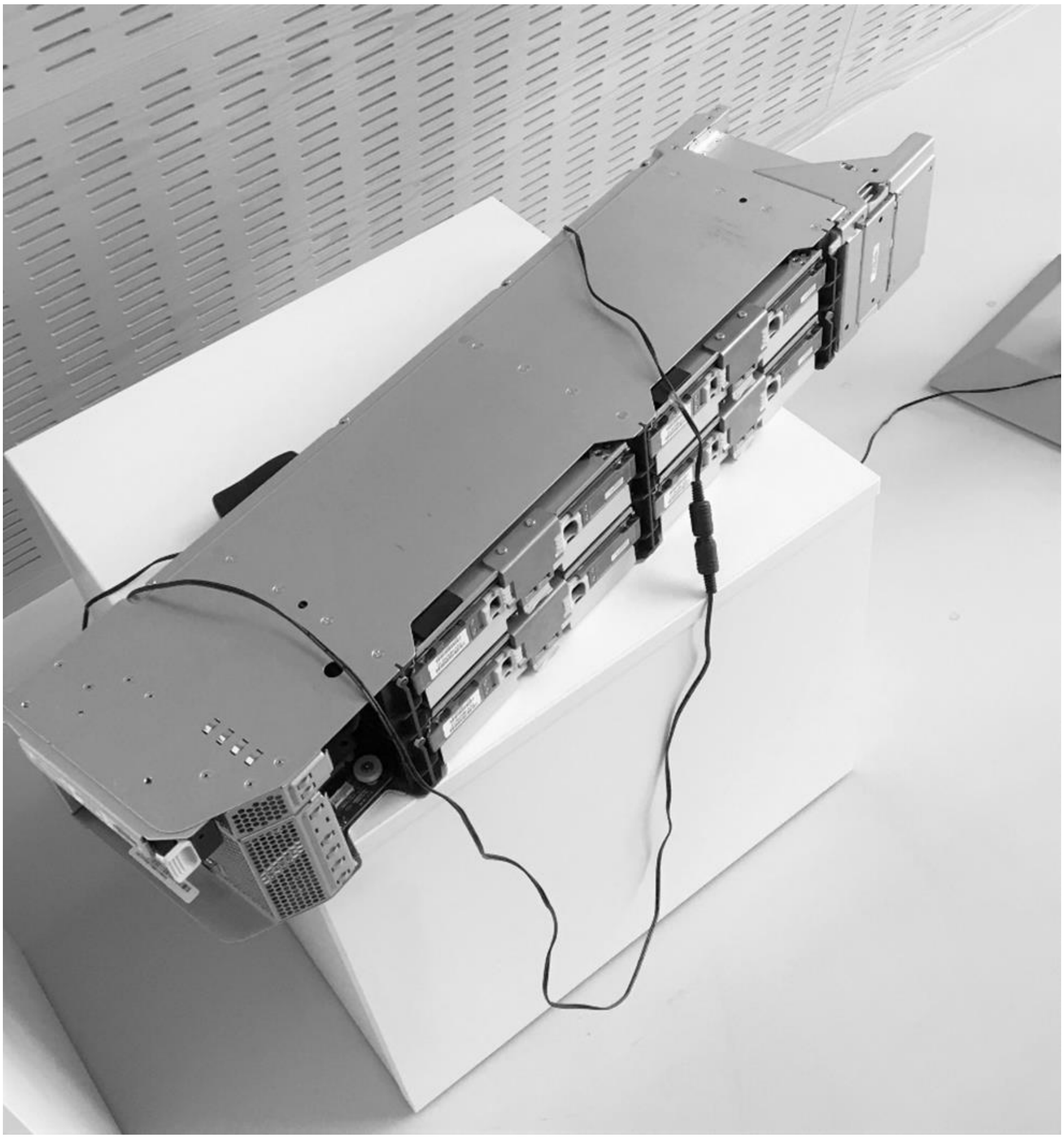

Figure 6. Server from the Facebook datacentre on display to exemplify this most recent addition to industrial excess heat. Source: Caroline Anna Salling, October 27, 2020.

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 figure 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 acceptable parameters. A new wing of the recently opened Fyn District Heating 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, it also indexes its existence. To put it simply, the organization is more important to Facebook® than to Fyn District Heating. While 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, Fyn District Heating'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 are involved in heat pump operations. 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. Then they wait for the datacentre workers to sort out whichever issues may cause malfunction. The dyad between the electrified cooled conditions during datacentre uptime and the 'heat death' of downtime is the most critical interplay in datacentre management work (Gonzalez Monserrate 2023). During the planning and construction phase, several of Jens' 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 and therefore never become involved in the internal stresses and maintenance work that downtime requires. It is the utility workers' job to make the industrial excess heat hot enough for consumption by Fyn District Heating, which is a task that does not require much collaboration between the recently converged infrastructures. In contrast, Jens explains, within district heating distribution work, such critical situations are rare as it at most operates with 'planned interruption', such as when certain pipes need replacement. Many future interruptions may cause the use of other fuels to supply Odense with heat when the servers are down. Yet, even if Facebook® may close the datacentre fully, the security of constant supply has been concretized in the infrastructure plan—Fyn District Heating has calculated the costs of installing large air source heat pumps on the field next to the datacentre and Fyn District Heating's new building currently wildly growing with grasses and flowers. Jens assures everyone that asks about how dependent Fyn District Heating is on Facebook® that there are plenty of alternatives to the server air already measured and accounted for.

Fyn District Heating's infrastructure is purposely engineered with lots of doors for the admission of public interest, in both organizational and architectural terms. 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. Energy production work is in comparison in no need 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 hard-boundary enclosed sufficiently, then the scaled industrial excess from servers takes centre stage as an effective, circular sustainability project.

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 environmental, climatic, and ecological effects beyond corporate sustainability reports. The utility workers' engineering approach to the material of excess affords a guiding path. Particularly with their perspective as excess as unavoidable when consuming fuels and producing commodities. Studying the techniques of major industries in relation to energy, which go largely unregulated and unchallenged, can be aided with the knowledge that it is not excess in itself that is a solvable problem. The maintenance and growth of industrial and utility relations is an understudied topic in STS. This analysis shows that there are several admission points into studying the tools of that trajectory, one of which is industrial excess. This material which we treat as an analytical concept can be labelled as neither the point of production nor consumption but, rather, the bridge that holds these more-than-economic processes together. Such studies can pay empirical and analytical attention to utility work and how it facilitates and is appropriated for revamping or inventing industrial adventures for new, profit-seeking corporations.

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. In a further contrast, if the digital industrialisation of Facebook® was studied solely on the basis of its sustainability report and fieldwork on datacentre operations, the inevitable conclusion would be that Facebook® consumes 100 per cent renewable energy and has enabled circular heat recovery projects. The utility plan shields the energy system against high pollution impacts of digital industrialisation at a municipal scale but exposes its climatic consequences at a transnational scale. The classification work that the utility engineers' employ to re-energize industrial excess at a time when the decarbonization of energy infrastructures is necessary for the survival within multiple, connected ecological emergencies is reflected in how hyperscale digital industrialization is carried out through means that cannot be decarbonized unless levels and modes of digital-industrial production become space for formal intervention.

A non-profitable utility can, via engineering transformation, utilise the industrial excess of companies, such as server air from digital twenty-first-century multinational platform companies. But only on the strength of the societal utility from handling industrial excess prioritised higher than potential economic benefits such as profit maximisation. But the benefit in advertising and making publicly visible the act of societal utilisation is, at current, nowhere near the level of incentive of profit maximising companies causing the industrial excess to advertise the utilised object as a result of own initiative, expertise and investment. Our study shows how Facebook® works to present the handling of industrial excess as an internal procedure while building walls around the industrial excess itself. Industrial excess makes the bridge between infrastructures that facilitate industrialisation and infrastructures that produce industrialisation. As the energy utility engineers convey, materiality is always already excessive. Many corporations are skilled in safeguarding industrial materials behind factory walls, and Facebook's® datacentres are no exception. Hot air from data servers is labelled as easily recyclable waste on the fabricated outside but inside the factory it is central to Facebook's® sustainability strategy claiming to use and produce circular production and consumption chains. 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, to ensure profit maximisation on the central affordance of digitalisation: personalized, immediate, centralized, digital, commercial advertising.

The utility as a figure holds radical potential as it handles and makes useful the excesses of late, including digital, industrialisation, prioritising cheap and equal, local access and ecological transformation. Not all utility companies, organisations, and infrastructures fit accordingly with this figure of non-profitable radical transformation and maintenance, but it could as a result of municipal and cooperative re-thinking and re-investments. Just as these utility work processes also come to benefit anyone interested in benefiting, including Facebook®, the vernacular carving out of the figurative components of excess, which we have followed, also benefits critical analysis. Industrialisation depends equally on its own often inaccessible methods (access only for business partners!) as it does on encroaching on the maintenance tools of non-profitable public, commonly owned, utilities. 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. This attention is crucial because finance, rather than merely competitive markets, eventually comes to guide interventions in the name of decarbonization. While the 'before' and 'during' of digital industrialisation has concretized both via boundary making between industries and utilities as well as scaling up both economic and energetic operations, then its 'after' is reflected in infrastructure plans that also account for the prospective decay of digital industries, certainly commensurate with the outsourcing and collapse of many a historical industry. Coming to terms with not the material but the industrial problems with excess will turn out critical in making possible such futures.

Acknowledgements

A major thanks to the utility workers whom this work would have been impossible without, as well as to Brit Ross Winthereik for supporting both the process and the analysis.

Author Biographies

Caroline Anna Salling is a Postdoc at the Department of Anthropology, University of Copenhagen with a PhD degree from the Technical University of Denmark. She is interested in ways that humans re-organise themselves in accordance with ecological transformation and the issues and potentials that arise thereof. Her main focus is on energy, utility and economic infrastructures and the way in which they are experimented with and intervened into to decrease their effects on emissions-induced climate change and ecological destruction.

James Maguire is an anthropologist and Associate Professor at the IT University of Copenhagen. His research is oriented towards questions arising at the intersection of climate and computation, particularly around themes such as energy, data, and digital infrastructures.

References

Ahmann, Chloe, and Alison Kenner. 2020. "Breathing Late Industrialism." *Engaging Science, Technology, and Society* 6(Nov): 416–38. https://doi.org/10.17351/ests2020.673.

Alexander, Catherine, and Joshua Reno, eds. 2012. *Economies of Recycling: The Global Transformation of Materials, Values and Social Relations*. London: Zed Books.

Au, Yung. 2024. "Data Centres on the Moon and Other Tales: A Volumetric and Elemental Analysis of the Coloniality of Digital Infrastructures." *Territory, Politics, Governance* 12(1): 12–30. https://doi.org/10.1080/21622671.2022.2153160.

Ballestero, Andrea, and Yesmar Oyarzun. 2022. "Devices: A Location for Feminist Analytics and Praxis." *Feminist Anthropology* 3(2): 227–33. https://doi.org/10.1002/fea2.12108.

Balzam, Guy, and Noam Yuran. 2022. "Assetization and the Logic of Venture Capital, or Why Facebook Does Not 'Feel' Like a Monopoly to Zuckerberg." *Science as Culture* 31(1): 107–20. https://doi.org/10.1080/09505431.2021.1990874.

Barclay, William J., Jr., and Mitchell Stengel. 1975. "Surplus and Surplus Value." *Review of Radical Political Economics* 7(4): 48–64. https://doi.org/10.1177/048661347500700404.

Bataille, Georges. [1949] 1991. *The Accursed Share*, Volume 1. Translated by Robert Hurley. New York: Zone Books.

———. 1985. *Visions of Excess: Selected Writings 1927–1939*. Edited by Allan Stoekl. Translated by Carl R. Lovitt and Donald M. Leslie Jr. Minneapolis: University of Minnesota Press.

Birch, Kean, and Kelly Bronson. 2022. "Big Tech." *Science as Culture* 31(1): 1–14. https://doi.org/10.1080/09505431.2022.2036118.

Boudia, Soraya, Angela N. H. Creager, Scott Frickel, and Emmanuel Henry, et al. 2018. "Residues: Rethinking Chemical Environments." *Engaging Science, Technology, and Society* 4: 165–78. https://doi.org/10.17351/ests2018.245.

Bowker, Geoffrey, and Susan Leigh Star. 1999. *Sorting Things Out: Classification and Its Consequences*. Cambridge, MA: MIT Press.

Bresnihan, Patrick, and Patrick Brodie. 2021. "New Extractive Frontiers in Ireland and the Moebius Strip of Wind/Data." *Environment and Planning E: Nature and Space* 4(4): 1645–64. https://doi.org/10.1177/2514848620970121.

Brodie, Patrick. 2020. "Stuck in Mud in the Fields of Athenry': Apple, Territory, and Popular Politics." *Culture Machine* 19: 1–34. https://culturemachine.net/vol-19-media-populism/stuck-in-mud-in-the-fields-of-athenry-patrick-brodie/.

———. 2021. "Hosting Cultures: Placing the Global Data Centre 'Industry.'" *Canadian Journal of Communication* 46(2): 151–76. https://doi.org/10.22230/cjc.2021v46n2a3773.

Buck, Holly Jean. 2022. "Mining the Air: Political Ecologies of the Circular Carbon Economy." *Environment and Planning E: Nature and Space* 5(3): 1086–1105. https://doi.org/10.1177/25148486211061452.

Buck, Holly Jean, Wim Carton, Jens Friis Lund, and Nils Markusson. 2023. "Countries' Long-Term Climate Strategies Fail to Define Residual Emissions." *Nature Climate Change* 13(4): 317–319. https://doi.org/10.1038/s41558-023-01614-7.

Burrell, Jenna. 2020. "On Half-Built Assemblages: Waiting for a Data Center in Prineville, Oregon." *Engaging Science, Technology, and Society* 6(June): 283–305. https://doi.org/10.17351/ests2020.447.

Callon, Michel. 1998. "An Essay on Framing and Overflowing: Economic Externalities Revisited by Sociology." *The Sociological Review* 46(1): 244–69. https://doi.org/10.1111/j.1467-954X.1998.tb03477.x.

Campbell, Nancy D. 2022. "Transnationalizing Critical Drug Studies." *Engaging Science, Technology, and Society* 8(3): 63–86. https://doi.org/10.17351/ests2022.873.

Carton, Wim, Adeniyi Asiyanbi, Silke Beck, and Holly J. Buck, et al. 2020. "Negative Emissions and the Long History of Carbon Removal." *WIREs Climate Change* 11(6): e671. https://doi.org/10.1002/wcc.671.

Caussarieu, Maëlle. 2021. "Energy System Transition in the Making: Case Study of Greater Copenhagen District Heating Network." PhD diss., Aalborg University. https://doi.org/10.54337/aau443829316.

Chen, Zhuo, Bryan Tilt, and Shaozeng Zhang. 2022. "Epistemic Turbulence in Renewable Energy Engineering on the Chinese 'Belt and Road.'" *Engaging Science, Technology, and Society* 8(2): 14–34. https://doi.org/10.17351/ests2022.1161.

Childs, Quincy. 2022. "'This Has Nothing to Do with Clouds': A Decolonial Approach to Data Centers in the Node Pole." *Commonplace*, June 29, 2022. https://doi.org/10.21428/6ffd8432.59c985d5.

Choy, Timothy. 2020. "A Commentary: Breathing Together Now." *Engaging Science, Technology, and Society* 6(Nov): 586–90. https://doi.org/10.17351/ests2020.771.

Cirolia, Liza Rose, Rike Sitas, Andrea Pollio, and Alexis Gatoni Sebarenzi, et al. 2023. "Silicon Savannahs and Motorcycle Taxis: A Southern Perspective on the Frontiers of Platform Urbanism." *Environment and Planning A: Economy and Space* 55(8): 1989–2008. https://doi.org/10.1177/0308518X231170193.

CLEAR. 2021. *CLEAR Lab Book: A Living Manual of Our Values, Guidelines, and Protocols*. Vol. 3.0. St. John's, NL: Civic Laboratory for Environmental Action Research, Memorial University of Newfoundland and Labrador. https://civiclaboratory.nl/clear-lab-book/.

Cooper, Zane Griffin Talley. 2021. "Of Dog Kennels, Magnets, and Hard Drives: Dealing with Big Data Peripheries." *Big Data & Society* 8(2): 20539517211015430. https://doi.org/10.1177/20539517211015430.

Corvellec, Hervé, Alison F. Stowell, and Nils Johansson. 2022. "Critiques of the Circular Economy." *Journal of Industrial Ecology* 26(2): 421–32. https://doi.org/10.1111/jiec.13187.

Cowen, Deborah. 2014. *The Deadly Life of Logistics: Mapping Violence in Global Trade.* Minneapolis: University of Minnesota Press.

Daggett, Cara New. 2019. *The Birth of Energy: Fossil Fuels, Thermodynamics, & The Politics of Work*. Durham, NC: Duke University Press.

Daniel, François-Joseph. 2022. "Industrializing Bacterial Work: Microbiopolitics, Biogas Alchemy, and the French Waste Management Sector." *Science, Technology, & Human Values* 48(5): 1223-1244. https://doi.org/10.1177/01622439221119851.

Danish Energy Agency. 2022a. "Analyseforudsætninger Til Energinet 2022: Datacentre." https://ens.dk/analyser-og-statistik/analyseforudsaetninger-til-energinet.

———. 2022b. "Klimastatus Og -Fremskrivning." https://ens.dk/analyser-og-statistik/klimastatus-og-fremskrivning.

Dunlop, Tessa. 2022. "Energy Efficiency: The Evolution of a Motherhood Concept." *Social Studies of Science* 52(5): 710–32. https://doi.org/10.1177/03063127221096171.

Dyrbye, Holger, and Jørgen Thomsen. 1999. *Spænding i Fællesskab: I/S Fynsværket 50 Odense År* [Collective Current. 50th Anniversary of the Fyn Energy Plant General Partnership].

Edensor, Tim. 2005. "The Ghosts of Industrial Ruins: Ordering and Disordering Memory in Excessive Space." *Environment and Planning D: Society and Space* 23(6): 829–49. https://doi.org/10.1068/d58j.

Energy Supply. 2019. "Kritik: Facebook-datacenter bliver 100 procent CO2-neutralt - med norsk vind," September 12, 2019. https://www.energy-supply.dk/article/view/676156/kritik_facebookdatacenter_bliver_100_procent_co2neutralt_med_norsk_vind.

Ensmenger, Nathan. 2021. "The Cloud is a Factory". In *Your Computer Is on Fire*, edited by Thomas S. Mullaney, Benjamin Peters, Mar Hicks, and Kavita Philip, 29–49. Cambridge, MA: MIT Press.

Fortun, Kim. 2012. "Ethnography in Late Industrialism." *Cultural Anthropology* 27(3): 446–64. https://doi.org/10.1111/j.1548-1360.2012.01153.x.

———. 2014. "From Latour to Late Industrialism." *HAU: Journal of Ethnographic Theory* 4(1): 309–29. https://doi.org/10.14318/hau4.1.017.

———. 2021. "Cultural Analysis In/Of the Anthropocene." *Hamburger Journal Für Kulturanthropologie* (HJK) 13: 15–35. https://journals.sub.uni-hamburg.de/hjk/article/view/1696.

Goldstein, Jesse. 2018. *Planetary Improvement: Cleantech Entrepreneurship and the Contradictions of Green Capitalism*. Cambridge, MA: MIT Press.

Gonzalez Monserrate, Steven. 2023. "Thermotemporalities, Thermomasculinities: Uptime, Downtime, and Server Heat in the Digital Anthropocene." *New Media & Society* 25(2): 324–44. https://doi.org/10.1177/14614448221149938.

Greene, Daniel. 2022. "Landlords of the Internet: Big Data and Big Real Estate." *Social Studies of Science* 52(6): 904–27. https://doi.org/10.1177/03063127221124943.

Grosz, Elisabeth A. 2001. *Architecture from the Outside: Essays on Real and Virtual Space*. Cambridge, MA: MIT Press.

Günel, Gökçe. 2022. "Accumulation: Exploring the Materiality of Energy Infrastructure." In *The Palgrave Handbook of the Anthropology of Technology*, edited by Maja Hojer Bruun, Ayo Wahlberg, Rachel Douglas-Jones, Cathrine Hasse, Klaus Hoeyer, Dorthe Brogård Kristensen, and Brit Ross Winthereik, 689–702. Singapore: Springer.

Haraway, Donna. 1997. *Modest_Witness@Second_Millennium.FemaleMan_Meets_OncoMouse*. New York: Routledge.

Hockenberry, Matthew. 2021. "Redirected Entanglements in the Digital Supply Chain." *Cultural Studies* 35(4–5): 641–62. https://doi.org/10.1080/09502386.2021.1895242.

Hogan, Mél. 2018. "Big Data Ecologies." *Ephemera: Theory & Politics in Organization* 18(3): 631–57. https://ephemerajournal.org/contribution/big-data-ecologies.

——. 2021. "The Data Center Industrial Complex." In *Saturation: An Elemental Politics*, edited by Melody Jue and Refico Ruiz, 283-305. Durham, NC: Duke University Press.

Hogan, Mél, Dustin Edwards, and Zane Griffin Talley Cooper. 2022. "5 Things about Critical Data Center Studies: On Elemental Thinking." *Commonplace*, October 31, 2022. https://doi.org/10.21428/6ffd8432.af5934aa.

Huber, Matthew T. 2022. *Climate Change as Class War: Building Socialism on a Warming Planet*. New York, and London: Verso Books.

Johnson, Alix. 2019. "Data Centers as Infrastructural In-Betweens: Expanding Connections and Enduring Marginalities in Iceland." *American Ethnologist* 46(1): 75–88. https://doi.org/10.1111/amet.12735.

Jørgensen, Bastian. 2021. "Becoming Data-Driven? The Reconfiguration of Work Situations in the Danish Customs and Tax Administration." PhD diss., IT University of Copenhagen. https://pure.itu.dk/en/publications/becoming-data-driven-the-reconfiguration-of-work-situations-in-th.

Judge, Peter. 2018. "Facebook signs for 294MW of wind power in Norway," *Datacenter Dynamics*, May 24, 2025. https://www.datacenterdynamics.com/en/news/facebook-signs-for-294mw-of-wind-power-in-norway/.

Kobus, James, Ali Ibrahim Nasrallah, and Jim Guidera. 2021. "The Role of Corporate Renewable Power Purchase Agreements in Supporting Wind and Solar Deployment." Columbia University: Center on Global Energy Policy. https://www.energypolicy.columbia.edu/sites/default/files/pictures/PPA%20report,%20designed%20v4,%203.17.21.pdf.

Lehuedé, Sebastián. 2022. "Territories of Data: Ontological Divergences in the Growth of Data Infrastructure." *Tapuya: Latin American Science, Technology and Society* 5(1): 2035936. https://doi.org/10.1080/25729861.2022.2035936.

Levenda, Anthony M, and Dillon Mahmoudi. 2019. "Silicon Forest and Server Farms: The (Urban) Nature of Digital Capitalism in the Pacific Northwest." *Culture Machine* 18: 1–18. https://culturemachine.net/vol-18-the-nature-of-data-centers/silicon-forest-and-server-farms/.

Liboiron, Max, and Josh Lepawsky. 2022. *Discard Studies: Wasting, Systems, and Power*. Cambridge, MA: MIT Press.

Maguire, James, and Brit Ross Winthereik. 2021. "Digitalizing the State: Data Centres and the Power of Exchange." *Ethnos* 86(3): 530–551. https://doi.org/10.1080/00141844.2019.1660391.

Meta. 2022. "2021 Sustainability Report". *Meta Sustainability.* Accessed October 12, 2023. https://sustainability.atmeta.com/resources/.

Moore, Sarah A. 2009. "The Excess of Modernity: Garbage Politics in Oaxaca, Mexico." *The Professional Geographer* 61(4): 426–37. https://doi.org/10.1080/00330120903143375.

Munn, Luke. 2021. "Imperfect Orchestration: Inside the Data Center's Struggle for Efficiency." *Computational Culture* 8(July). http://computationalculture.net/imperfect-orchestration-inside-the-data-centers-struggle-for-efficiency/.

Murphy, Michelle. 2013. "Distributed Reproduction, Chemical Violence, and Latency." *The Scholar & Feminist Online* 11(3). https://sfonline.barnard.edu/distributed-reproduction-chemical-violence-and-latency/.

———. 2017. "Alterlife and Decolonial Chemical Relations." *Cultural Anthropology* 32(4): 494–503. https://doi.org/10.14506/ca32.4.02.

Neilson, Brett, and Tanya Notley. 2019. "Data Centres as Logistical Facilities: Singapore and the Emergence of Production Topologies." *Work Organisation, Labour & Globalisation* 13(1): 15–29. https://doi.org/10.13169/workorgalaboglob.13.1.0015.

Ofrias, Lindsay. 2017. "Invisible Harms, Invisible Profits: A Theory of the Incentive to Contaminate." *Culture, Theory and Critique* 58(4): 435–56. https://doi.org/10.1080/14735784.2017.1357478.

Pan, Darcy. 2022. "Storing Data on the Margins: Making State and Infrastructure in Southwest China." *Information, Communication & Society* 25(16): 2412–26. https://doi.org/10.1080/1369118X.2022.2077125.

Pasek, Anne. 2019. "Managing Carbon and Data Flows: Fungible Forms of Mediation in the Cloud." *Culture Machine* 18: 1–15.

Pfotenhauer, Sebastian, Brice Laurent, Kyriaki Papageorgiou, and Jack Stilgoe. 2022. "The Politics of Scaling." *Social Studies of Science* 52(1): 3–34. https://doi.org/10.1177/03063127211048945.

Poon, Martha. 2016. "Corporate Capitalism and the Growing Power of Big Data: Review Essay." *Science, Technology, & Human Values* 41(6): 1088–1108. https://doi.org/10.1177/0162243916650491.

Rossiter, Ned. 2016. *Software, Infrastructure, Labor: A Media Theory of Logistical Nightmares*. New York: Routledge Taylor & Francis.

Salling, Caroline Anna. 2024. "From Incentives to Instructions: Climate Policy Mechanisms on Heat Pumps, Datacentres, District Heating, and Epistemic Collisions Hindering Decarbonisation in Practice." *Energy Research & Social Science* 111(May): 103469. https://doi.org/10.1016/j.erss.2024.103469.

Salling, Caroline Anna, and Brit Ross Winthereik. 2025. Inventorying Data: Circumvented Investment Conditions by Big Tech's Supply Chain Capitalism. *Journal of Cultural Economy.* https://doi.org/10.1080/17530350.2024.2436873.

Schiølin, Kasper. 2020. "Revolutionary Dreams: Future Essentialism and the Sociotechnical Imaginary of the Fourth Industrial Revolution in Denmark." *Social Studies of Science* 50(4): 542–66. https://doi.org/10.1177/0306312719867768.

Star, Susan Leigh. 2010. "This Is Not a Boundary Object: Reflections on the Origin of a Concept." *Science, Technology, & Human Values* 35(5): 601–17. https://doi.org/10.1177/0162243910377624.

Starosielski, Nicole. 2022. *Media Hot and Cold*. Durham, NC: Duke University Press.

Sutcliffe, Thomas Edward. 2022. "Consumption Work in Household Circular Economy Activities: Findings from a Cultural Probe Experiment." *Journal of Cultural Economy* 15(5): 568–83. https://doi.org/10.1080/17530350.2022.2066150.

Taylor, A.R.E. 2018. "Failover Architectures: The Infrastructural Excess of the Data Centre Industry." *FA: Failed Architecture* (blog), May 19, 2018. https://failedarchitecture.com/failover-architectures-the-infrastructural-excess-of-the-data-centre-industry/.

Tsing, Anna. 2009. "Supply Chains and the Human Condition." *Rethinking Marxism* 21(2): 148–76. https://doi.org/10.1080/08935690902743088.

UN (United Nations). n.d. "Goal 12: Ensure Sustainable Consumption and Production Patterns". *UN Sustainable Development Goals.* Accessed October 12, 2023. https://www.un.org/sustainabledevelopment/sustainable-consumption-production/.

Velkova, Julia. 2016. "Data That Warms: Waste Heat, Infrastructural Convergence and the Computation Traffic Commodity." *Big Data & Society* 3(2): 1–10. https://doi.org/10.1177/2053951716684144.

———. 2021. "Thermopolitics of Data: Cloud Infrastructures and Energy Futures." *Cultural Studies* 35(4–5): 663–83. https://doi.org/10.1080/09502386.2021.1895243.

———. 2023. "Retrofitting and Ruining: Bunkered Data Centers In and Out of Time." *New Media & Society* 25(2): 431–48. https://doi.org/10.1177/14614448221149946.

Vonderau, Asta. 2019. "Storing Data, Infrastructuring the Air: Thermocultures of the Cloud." *Culture Machine* 18: 1–12. https://culturemachine.net/vol-18-the-nature-of-data-centers/storing-data/.

Yusoff, Kathryn. 2009. "Excess, Catastrophe, and Climate Change." *Environment and Planning D: Society and Space* 27(6): 1010–29. https://doi.org/10.1068/d7407.

Zhang, Amy. 2020. "Circularity and Enclosures: Metabolizing Waste with the Black Soldier Fly." *Cultural Anthropology* 35(1): 74–103. https://doi.org/10.14506/ca35.1.08.

Zuboff, Shoshana. 2022. "Surveillance Capitalism or Democracy? The Death Match of Institutional Orders and the Politics of Knowledge in Our Information Civilization." *Organization Theory* 3(3): 26317877221129290. https://doi.org/10.1177/26317877221129290.