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Data that warms: Waste heat, infrastructural convergence and the computation traffic commodity

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Abstract

This article explores the ways in which data centre operators are currently reconfiguring the systems of energy and heat supply in European capitals, replacing conventional forms of heating with data-driven heat production, and becoming important energy suppliers. Taking as an empirical object the heat generated from server halls, the article traces the expanding phenomenon of 'waste heat recycling' and charts the ways in which data centre operators in Stockholm and Paris direct waste heat through metropolitan district heating systems and urban homes, and valorise it. Drawing on new materialisms, infrastructure studies and classical theory of production and destruction of value in capitalism, the article outlines two modes in which this process happens, namely infrastructural convergence and decentralisation of the data centre. These modes arguably help data centre operators convert big data from a source of value online into a raw material that needs to flow in the network irrespective of meaning. In this conversion process, the article argues, a new commodity is in a process of formation, that of computation traffic. Altogether data-driven heat production is suggested to raise the importance of certain data processing nodes in Northern Europe, simultaneously intervening in the global politics of access, while neutralising external criticism towards big data by making urban life literally dependent on power from data streams.

Keywords

Waste heat, data heat recycling, data furnace, computation traffic, big data, server cooling

Introduction

In 2011, a team of researchers at Microsoft published a paper in which they argued for the need to decentralise data centres and place servers in private living spaces as a way to offset problems with managing the heat that threatens server halls with disruptions (Liu et al., 2011). They called the system 'data furnaces'. The data furnace represents a high performance server designed to look like a heater which disperses the heat emitted in the process of networked computation into private living and office spaces. It is supposed to reduce the cost of waste heat management for the data centre by converting server heat into a new commodity to be sold to internet users. Internet users would also host the servers of the data centre in their private space and pay for doing so. The paper concludes that such a solution is environmentally friendly as it reduces the carbon footprint of the data industry and brings more profit to the data centre by eliminating the need to acquire land, pay for electricity and invest in cooling systems.

At the time when the paper was published, a modified version of this idea had already been implemented in the Finnish capital, Helsinki. In a Cold War bunker located under a cathedral near the city centre, the IT company Academica built a data centre and connected it to the pipes of the local district heating system, rerouting the waste heat from the servers to heat the water of 500 central apartments (Vela, 2010).

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Since then, similar solutions have been rapidly emerging in a number of European cities. Besides Helsinki, Stockholm, Paris and London have been at the forefront of pushing corporate imaginaries of a new role for data centres, as energy providers and important global data processing hubs. TelecityGroup in Paris has been rerouting its waste heat into an arboretum to grow plants (TelecityGroup, 2010). Telehouse West in London Docklands disperses heat from its server halls into the local district heating system and provides hot water to nearby houses (Telehouse, n.d.). In Stockholm, the internet service provider Bahnhof is experimenting with turning waste heat into the main source of heating in the Swedish capital while establishing standards for future 'green' data centres (Elementica, 2016; Triple Green, n.d.). This future is imagined to be 'not in the countryside, it is in cities with a well connected district heating system', Bahnhof's CEO proclaims (Bahnhof, 2015a). In confirming this statement, the Russian search engine Yandex opened in early 2016 a massive data centre in Mäntsälä, Finland that now provides the energy to heat water for 20,000 town inhabitants (DatacenterDynamics, 2015).

The examples above resemble a new wave of techno-optimism and are commonly veiled in a discourse of innovation, environmental friendliness and 'smarter' data processing. They are at the same time alarming as they normalise the production of big data and interconnect internet infrastructures with the critical infrastructures of urban life, that is the systems of water, energy and heat supply. As Halpern (2014) reminds, fantasies that connect large data streams with sustainability have been present for a while in contemporary urban development projects aimed at creating 'smart' cities powered with new media. Inspired by cybernetic imaginaries from the 1950s, such urban landscapes conceptualise data as a source of stability, wealth and sensory pleasure while converting it into a new raw material to mine, creating new orders of control and surveillance (Halpern, 2014: 5).

The bright sustainable future that data centre operators chart seems to take place in a universe in which the critical debates that surround big data do not exist, while cementing data production as a regime of computation that can literally power everyday life. An enquiry into the nature and implications of this expanding phenomenon is therefore urgent and represents the main objective of this article.

Big data has been defined as the capacity of certain actors to compute large data streams (boyd and Crawford, 2012). This capacity, possessed primarily by corporate data centre operators, internet service providers and government security agencies redefines our ontological and epistemological orientation in the world, bringing about issues of global surveillance, ethics, privacy, algorithmic governance, new digital divides and transformations of the public sphere (boyd and Crawford, 2012; Gillespie, 2014; Harper, 2016; Kitchin, 2014; Striphas, 2015).

This article extends these concerns by asking what kind of issues, practices, modes of valorisation and infrastructural interconnection arise when big data streams become the raw material that replaces older forms of energy supply in the urbanised world. Taking as an empirical object the heat generated from server halls, the article asks what implications does the use of waste heat for urban heating have on the economic, symbolic and institutional significance of data and data centre operators? What are the processes by which the data processing industry becomes an energy supplier, and with what societal consequences?

Drawing on new materialisms, infrastructure studies and classical theory of valorisation through waste in capitalism, the article suggests that by paying close attention to the ways in which urban infrastructures are rewired to transport waste heat, we could understand better the processes of ongoing renegotiations of the meaning, materiality and the value of digital data. Not least, we can see how the data industry contributes to extend the sphere of capitalist production and the digital economy by redefining waste into a desirable commodity.

Using examples from Stockholm and Paris, two modes of valorisation of waste heat are outlined: first through a process of infrastructural convergence, or the creation of links of dependencies through loops of energy transfer between the flows of data streams and those of urban energy supply. And, second, by obscuring power through dismantling the data centre spatially and moving it into our homes, converting it into yet another ephemeral artefact. The main contribution of the article is in showing how these two modes convert data from a source of value online into a broader resource of significance. In this process of conversion, a new commodity is emerging, that of computation traffic. This commodity arguably extends the power of data centre operators by allowing them to, first, valorise data online, and second, use big data streams as a raw material that has to increase and flow perpetually in the network irrespective of its meaning. The article concludes with a discussion of the broader implications of this emerging commodity.

Servers, hot and cold

Within media studies, heat and media temperatures have been referred to predominantly metaphorically, and more rarely as the main object of study. Mapping the historical terrains of the use of temperature in media studies, Starosielski (2014) reminds of four uses. The first, and more common, is McLuhan's (1994) metaphor of media as cold or hot which refers to the affective intensities that our engagements with different mediums evoke. Another use is in Shannon's theory of thermodynamics where heat describes the conductivity of communication technologies, whether or not they can transmit information. A third approach with Marxian roots refers to transformations of media over time, moving from one phase to another, or when media objects change form. Finally, heat as used by new materialisms has been concerned with the analysis of media environments and 'the expansive cooling infrastructure needed to dissipate communications heat' (Starosielski, 2014: 2506). The latter perspective is useful to map the context in which the infrastructures of big data are currently being rewired and to start charting the modes in which they transform the value, materiality and cultural meaning of data streams.

Materiality of media is both about the physicality of hardware, software, digital objects and artefacts, and about the material conditions of producing the digital (Munster, 2014). From a materialist perspective, as with any other body, media hardware radiates heat (Mulvin and Sterne, 2014). As a consequence, heat has always been a problem in electronics. Maxwell and Miller (2012: 27–30) note how in the famous essay by Gordon Moore from 1968 about the exponential increase in density of transistors on a chip, there is an overlooked section called 'Heat Problem'. In it, the heat generated by the components in a chip is regarded as an engineering problem that requires consideration. In 2011, the problem was solved by inventing a new chip called dark silicon (Maxwell and Miller, 2012: 28). Yet, if solved locally at the level of electronics, the problem of heat re-emerges in the broader context of the expansive infrastructures of networked data centres made of energy-hungry server halls.

In order for the signals of telecommunication networks to be pushed through the transoceanic fibre optic cables, cable stations need to be powered by electricity and cooled (Starosielski, 2015a: 66). However, only a minimal part of the energy that powers server rooms is actually needed to emit signals in the telecommunication network (Liu et al., 2011). Most of the input electricity is transformed into heat by the servers, which can become warm even when computing only a little, simply due to the close proximity of large numbers of machines located in a dense space. The heat increases during computing when a greater load is placed on the servers' processors.

Intense computation emerges from more than simply collecting data for surveillance purposes or for producing 'the cloud'. The digital version of the oldest new media, animation (Manovich, 2001), requires massive computation power, called render power, to be mobilised. In order to create their 3D films, Hollywood animation studios use thousands of servers with tens of thousands of cores to render their animations. Those who do not possess such computing power revert to the services of online render farms. These farms usually operate as part of data centres and cloud-computing infrastructure, and share their computational capacity. Because of this infrastructural coexistence, emerging major actors in the area of online distributed render power are, unsurprisingly, Google, through its ZYNC service, and Amazon through its Elastic Compute Cloud. Universities and other large-scale research facilities face similar needs for large-scale computation power.

Intense computation processes can make server rooms reach temperatures of 35–45°C that could result in server failure. Surprisingly, the effort that the industry exerts to offset this threat has largely evaded scholarly attention, which has instead predominantly discussed the input problem, the electricity.

In 2008 when Microsoft was adding 20,000 servers a month to its server farms and Google already had about half a million servers, 'the cloud' was consuming gigawatts of energy, representing about 2% of US electricity consumption, with prospects for doubling every five years (Maxwell and Miller, 2012: 29). Yet, just three years later the energy consumption of server halls surpassed 10% of the global electricity consumption (Cubitt et al., 2011). A much cited report from Greenpeace shows that up to 80% of this energy came from coal, making data centres a major polluting industry (Cook and Van Horn, 2011). This pollution is specific and it leaves carbon footprints, coal dust and exploits vast amounts of land needed to store the servers of the data centres (Gabrys, 2015).

Additional specificity is added by the emission of 'waste heat'. From a materialist perspective heat is an instance of a 'weird materiality' (Parikka, 2012), or a 'material immateriality' (Gabrys, 2015). It is 'weird' because it does not 'bend to human eyes and ears [and is] not only touchable objects, but also modulations of electrical, magnetic, and light energies, in which also power is nowadays embedded' (Parikka, 2012: 96). The 'weirdness' of heat stems from its ontology of being a form of energy in flux, one which is culturally constructed by the operators of data centres as 'dirt and bad matter' (Parikka, 2012: 98) as it threatens to halt communication, computation and economic flows. Waste heat threatens the information power gathered in the databases of user activity (Gillespie, 2014: 174) by destabilising the infrastructures of the data centres and the carefully crafted illusion of 'the cloud' that the industry has laboriously (and successfully) created (Durham Peters, 2016).

In order to offset this threat, data centres usually use water. Mel Hogan (2015) demonstrates how the National Security Agency constructed its surveillance data centre, the third largest on the planet, such that it requires 1.7 million gallons of water per day to keep its servers running. While half of the world's population lacks adequate access to clean water, Hogan notes how water is used for both propelling a surveillance machine and enabling the digital networked lives that we live:

> The huge amount of water currently required to manage our digital lives is inextricably linked to values we uphold, such as power and control, assumed to be inherent to Big Data and deeply rooted into the provisions of nature, while never fully committed to them. (Hogan, 2015: 7)

In Europe, new data centres tend to be built close to seas, rivers and lakes in order to ease the supply of water to server cooling systems. This is also one of the reasons why cities located in water abundant Northern Europe are becoming attractive locations for the data industry. At one of the largest data centres in London, PowerGate, TelecityGroup collects rain water, stores it and evaporates it in a controlled way into the atmosphere doing 'smart climate management' through 'free cooling' (TeleCity Engineering Group, n.d.).

Another way to offset waste heat is by relocating data centres to geographically colder locations, such as those in the Arctic climate zone, reshaping the topography of the internet infrastructure (Starosielski, 2014). A paradigmatic example has been Facebook's data centre in the city of Luleå in Northern Sweden, the first one to be opened outside of the US. While using as much energy as a steel plant, the centre, also called 'The Node Pole', cools down its servers by pumping outside air into the building and exhausting waste heat (Harding, 2015). Similar solutions have been implemented by Google's data centre in Finland and Apple's equivalent in Denmark.

A commonality of these approaches to cooling is that they treat heat as 'a matter out of place' (Douglas, 2002: 44). But whether matter is in the right or wrong place in telecommunication systems is negotiated in the process of capitalist production. The next section extends the materialist framework by revising theories that help relate waste heat to circuits of commodity production and circulation, value and power.

Waste, value and infrastructural stability

As a material and cultural category, waste is never an end point. Inherent to capitalism and its need to expand, waste is created in the dialectical processes of production and consumption, both of which are contingent on the supply of raw material and the availability of infrastructures to transport and process it. What is of value and what is its opposite, i.e. waste, is determined by the interested parties in the production process. Waste could be a by-product of production, and equally a by-product of productive consumption, when the practice of consumption produces the raw material for new production and consumption practices to emerge (Bolin, 2011).

Waste is also an intermediate state and a boundary category in which an object is not in movement towards valorisation or devaluation but is temporarily exempted from value (Thompson, 1979). This state is important for two reasons. First, Thompson notes that at each moment in time an object is located on a specific trajectory of valorisation, either increasing its value over time, and hence becoming durable, or decreasing its value and becoming transient. The conversion from transient to durable takes place when something becomes waste, an object of no value and no projected lifespan. If 'discovered', the object can increase in value and lead to the creation of new commodities. Second, the possibility for these transfers to occur permits the maintenance of social boundaries and the uneven distribution of power in society (Thompson, 1979: 109). Simply put, those who have the power to define what is valuable in a society (including redefining waste as a valuable asset) are those who produce and maintain difference.

In a capitalist system, raw materials need to be constantly reinvented in order to allow capital to expand. As discussed above, the raw material that powers the data infrastructures, at least in the US, has been predominantly coal. Yet such raw material is insufficient to create surplus value in the digital economy, which also depends on creating symbolic raw materials, such as audiences for advertisers to mine (Bolin, 2011: 36), or internet users to be fed to algorithms (Gillespie, 2014: 173). Occasionally, waste also needs to be converted into a symbolic raw material in order to expand the digital economy.

In the context of the internet infrastructures, spam is a good example of the latter. Spam is ambiguous garbage and it is simultaneously the agent that clogs bandwidth and the ever multiplying by-product of this clogging (Brunton and Coleman, 2014). It is quotidian yet rarely noticed or read by those who receive it. Despite hijacking bandwidth, spam has been valuable not only for the economic practices of the dark internet (Brunton and Coleman, 2014), but also as Bolin (2014) notes, for internet service providers because it creates traffic, a commodity that is produced by the flow of visitors to websites (van Couvering, 2008).

In the case of waste heat, its conversion into a raw material of value could not happen at once.

An important step in the process was the phase when data centre infrastructure operators constructed ‘the cloud’ and themselves as powerful nodes on which the digital economy depends.

The creation of the cloud has been predicated upon aggregating and centralising user information management, moving it away from users’ personal computers. As Jakobsson and Stiernstedt (2012) show, this move had to be perceived as safe. This perception has been carefully crafted by deliberately inscribing the data centre in the temporalities of geological, historical and technological change, placing data centres in history through which they become part of a desired future. Stories about the formation of Earth’s surface, the bedrock and broadly geological, political and economic stability have been used particularly in the Nordic countries to define data centres as eternal, and hence durable (Jakobsson and Stiernstedt, 2012).

Once objects are defined as valuable they also tend to increase in aesthetic value (Thompson, 1979: 33). Aerial photos of sleek containers embedded in scenic landscapes, clean server rooms with shiny pipes, colourfully blinking electronics and James Bond-inspired interiors hyper stylise data centres and make the visual argument that the landscape becomes more beautiful through data (Holt and Vonderau, 2015). Making data beautiful is also intrinsically related to the process of making data useful (Halpern, 2014). Yet, as long as heat remains waste within the data centre it acts as a material force that devalues this so effortfully and carefully constructed social image of durable data and its extended utilisation. Waste heat acts as the major agent of disruption *from within* the data centre and threatens its power through the threat of network instability, transience and decay.

Destabilisation is a common problem for global communication flows, one that requires constant effort, strategic material and cultural interventions to offset disturbances (Graham and Thrift, 2007; Jackson, 2014; Starosielski, 2015b). One of the main ways to stabilise the internet infrastructure has been through what Starosielski (2015b: 18) calls ‘strategies for interconnection’. By this she means the process of adding cultural and material layers of insulation that facilitate the transfer of multiple forms of energy between the systems of the cable network and the cultural geographies into which it is inserted, keeping the network in equilibrium. Such strategies have ranged from using the ocean to ground the signals transferred through fibre optic cables, to arranged marriages between workers in order to help ‘sustain the operators and therefore stabilise transoceanic signal traffic in remote locales’ (Starosielski, 2015b: 19).

Commodifying waste heat can therefore represent a way to insulate the data centre network from inner disturbances, and therefore stabilise it. Not least, it can help bring attention to a new commodity that the data industry creates, that of computation traffic, while neutralising external criticism by reframing data production as environmentally responsible and necessary for everyone’s well-being. The next sections illustrate how this process happens through discussing examples from Stockholm and Paris.

Infrastructural convergence

One emerging approach to commodifying waste heat is through infrastructural convergence. To explain the process I will use as an example the workings of Bahnhof, a Swedish internet service provider that has recently constructed a number of data centres in Stockholm, in a way that rewires the systems of energy supply in the Swedish capital to become contingent on data.

Founded in 1994, Bahnhof was one of the first internet providers in Sweden and aims to deliver ‘Internet with privacy’ as its slogan reveals. Bahnhof adhered to this principle on multiple occasions. It has been providing hosting services to Wikileaks since Amazon stopped servicing it in 2010. It also offered free VPN encryption to all its clients when the European Union passed the data retention directive in 2014 that forced all internet service providers to collect data from their users, thus making such collection worthless (Bahnhof, 2014).

The data centre that hosts Wikileaks is Pionen. Inaugurated in 2008 in a Cold War nuclear bunker in the city centre, Pionen attained a cult status for its futuristic cyber-utopian design largely inspired by popular culture, and the symbolism of its location which in the event of a cataclysm would likely be one of the few that would remain intact, signifying the value of the data hosted there (Holt and Vonderau, 2015; Jakobsson and Stiernstedt, 2012).

While providing cloud services online, Bahnhof also created a visible cloud of steam in central Stockholm, which for years was a cause of anxiety for citizens. In a 2015 press release, the company explained that the cloud of steam was generated by its underground servers. It also announced its new project to eliminate the visually disturbing sight of the steam cloud by routing heat into the pipes of the district heating system in this part of Stockholm (Bahnhof, 2015b).

Bahnhof’s solution was to create a large cooling plant inside the data centre that would absorb the waste heat from the servers and pump it in the homes of the city dwellers. The system was serviced by Fortum, one of Stockholm’s largest electricity and district heating providers (Open District Heating, n.d.). As of 2016, the plant’s waste heat is said to provide a constant supply of between 600 kW and 1 MW of heat with a delivery temperature of 68°C (Open District Heating, n.d.).

The streams of waste heat that enter homes, shops and offices in Stockholm currently pair the production of digital data with the residents' sensory experiences of ambience. This process of integration literally shows how heat can move 'across and through infrastructure, ecologies, and bodies' (Starosielski, 2014: 3). As Larkin (2013) reminds us, infrastructures are able to influence sensory experiences of softness, hardness, the noise of a city or the feeling of being hot or cold, affecting perceptions of temporality, speed and the sense of what it is to be modern and part of a specific future.

The future of Bahnhof is one of intervening in the energy politics of the Swedish capital through computing data and providing heating with it, attempting to eliminate older forms of energy supply and convert the data centre into an essential energy provider. The cooling plant in Pionen, likewise in other data centres is far larger than the current capacity requires (Open District Heating, n.d.). In building a cooling system on such a scale, Bahnhof reflects the general principle of the telecommunication cable industries' to bind their economic models and infrastructures to a projection of media as an ever-expanding resource to be capitalised on (Starosielski, 2015a). The value of the heat fluctuates, based not on the servers' temperature but on the outdoor temperatures making servers in colder climates economically more profitable, strengthening the attractiveness of northern locations: 'On a cold winter's day one megawatt hour can be worth ten times as much as on an ordinary summer's day. Bahnhof still knows that it has made a good investment' (Open District Heating, n.d.).

Since Pionen, Bahnhof and Fortum have built three larger data centres in Stockholm with this system in place and two more are in the planning stage. One of them is intended to be Stockholm's largest data centre code named Elementica. Admitting that the new '21 megawatt monster' is a heavy industry project, its creators nevertheless promise it will be the world's most modern and climate smart data centre. They envision a future where Stockholm is Northern Europe's internet hub, *replacing* the main sources of heating for the capital with the waste heat from the data centre (Bahnhof, 2016; Elementica, 2016). Elementica is estimated to generate 112 GW h of heat per year and provide that heat to 20,000 households.

Such a replacement is significant for converting the production of data from a source of value online into a raw material to power urban life. Yet, the success of the imaginary that underpins this multimillion investment is crucially dependent on the ability of data centre operators to fill the data processing and storage capacity of these oversized centres. This need implies that we are still to see an increase in the intensity of the generation of big data, while the projected infrastructures that anticipate such production already create firm dependencies between the ambient experience of comfort of city dwellers and the need for increased data production and computation.

When new infrastructures are established they tend to be layered upon older ones, creating historical lines that chart different temporalities and cultural contexts in which each layer has emerged (Star and Ruhleder, 1996). The type of infrastructural connection that Bahnhof makes is somewhat different. It is not about layering on top, but about converging older infrastructures with those of big data. The heat emitted by servers and its valorisation extends the process of media convergence beyond that of media formats and devices. Instead it becomes materially implicated with legacy infrastructures, transforming them and replacing their raw material with data and waste heat.

The spatial dismantling of the data centre

Another way to valorise waste heat in European capital cities, albeit on a smaller and more experimental scale, is through the attempts of providers of computation services to realise the idea of data furnaces.

One of the most successful examples so far is that of Qarnot computing, a French company that specialises in providing computation power rather than storage to banks, research institutes and animation studios. Founded in 2013, the company has created a 'smart' heater that represents 'a fusion of an electrical heater and a high-performance computer server' (Qarnot Computing, n.d.). The device is called Q.rad and produces heat by computation. When a client of Qarnot requires computing power to process financial data or render a scene of an animation film, the Q.rads are activated and each of them produces 500 W of energy that heats up a space of 13–25 m^2. If no computation is requested, the server pulls tasks from its cache or performs dummy calculations to emit heat. The electrical consumption is measured by an embedded meter, and the bill is sent to the client who ordered the computation, rather than the one who used the heat. Since 2013, the company has installed 300 such heaters in Paris apartment blocks and 25 in the Telecom ParisTech incubator, with plans for expanding to the Nordic countries, the US and China.[1]

In this scheme of valorising waste heat, the space of private homes and office buildings becomes the infrastructure that bears the data centre, supplies it with electricity and cools it down. The home becomes a cooling environment and a node in the telecommunication network that ensures its stability. It powers it physically with electricity, cools it down and fills it symbolically with content through the more mundane online activities of the household members. The production of content does not directly heat the living space, but it supplies the network with more data, a justification for such infrastructure to be built at the first place. More importantly though, the members of the household are made involuntary into service staff that can observe and report the physical attributes of the heater, push buttons or carry out hard reboot of the server if requested, in the case of malfunction, or need of repair. These services are normally provided by dedicated staff at the data centre, but in Qarnot's configuration there is no need for such paid labour. There is also no central space in which such labour could potentially work. Data furnaces installed in private living spaces fiscally devalue the work of data centre maintenance. What the household members receive in return is a product that has sign value. It comes in the form of a supposedly enhanced sensory experience of comfort that the heat produced through computation creates. As Qarnot claims, it is 'a high quality "soft" heat as opposed to electrical convectors' (Qarnot Computing, n.d.). Such an aestheticised waste heat can provide residents with a sense of pleasure and evoke feelings of progress, of belonging to the future and of giving meaning to what it is to be a responsible producer of big data. In a campaign video by the Dutch company Nerdalize, which is experimenting with an identical approach to Qarnot in cooperation with the energy provider Eneco, an elderly couple shares their positive feelings about the new server heater they received:

> Does it buzz? Does it hiss? Does it gurgle? Does it beep? Not at all — it's completely silent! (giggle) — I just think the whole idea is brilliant — that rather than putting all those things together inside a single unit that you then need to cool, you spread them around instead, one by one, among private individuals so that everyone gets to benefit from it. I think that before long hundreds of families will start enjoying the benefits of this option. (Nerdalize, 2015)

Besides homes, other important nodes in the distributed data centre are schools where Qarnot has experimentally placed 50 server heaters to guarantee that even if households turn off the heaters on warm summer days, those in schools will keep computing and cool the network by emitting waste heat while students are on vacation (Judge, 2014). In addition to considerations about locations in which the servers could be placed as part of the topography of the internet, data centres anchor their infrastructures in the temporal cycles of social life and seasonal change.

To sum up, in this mode of valorising waste heat, the data centre is fragmentised, decentralised and its computing servers are moved into multiple private and public spaces. Such a move introduces a new degree of ephemerality to 'the cloud'. Its materiality and workings are veiled in a new degree of abstraction that is ever harder to locate. With materiality reconfigured, data centre service workers redefined and data ready to replace heat supply in private living spaces, the data centre rises in power and veils itself in deeper opacity.

In a certain way, this approach mirrors some earlier internet infrastructures such as the bit torrent protocol that made possible peer-to-peer file sharing. It also exhibits similarities to the commons-based peer production mode of creating value in the internet economy (Benkler, 2006). One lesson that these models of cultural production have taught us is that their emergence has come with a profound transformative charge that has altered economic, cultural and technological production, bringing about phenomena such as Wikipedia, Napster and concentrations of algorithmic power.

The concluding section of this article discusses the transformations that occur through the two modes of turning waste heat into a utility and their broader implications.

Transformations of data and the birth of the computation traffic commodity

We can see that with the intensification of big data production there have emerged particular locations in Europe where waste heat is being converted into a valuable asset and a raw material to mine by data centre operators. These developments are significant in several ways.

First, the creation of this raw material is a sign of the ongoing formation of a new commodity, that of *computation traffic*. Traffic as a commodity emerged after the Dotcom crash, as a result of the process of the reconfiguration of the web portals and the search engine market (Van Couvering, 2008). This reconfiguration implied that it was no longer as valuable to provide content to users as to increase and keep the flow of visitors, a move that led to search engines becoming outright winners. The traffic commodity was further developed by internet server providers and data centre operators that were able to aggregate and organise information about these flows and sell it to third parties. Bolin (2014) shows how this process extended the general traffic commodity and made it more specific by selling visitor data to advertisers. The cases discussed in this article show instead how data centre operators are attempting to create surplus value from *the flows of data* in the network and the need to process them and assure their stability rather than from the flows of visitors or audiences. This shift in focus signifies that digital data is starting to be valued by data centre operators first of all as a source of content or information that can be valorised back online, and then again, as a raw material that has to increase and flow perpetually in the network in order to stabilise it and generate energy to sell in urban areas. A logical implication is to see the appearance of novel media practices that could potentially fill the emerging infrastructures of waste heat circulation with computation traffic.

Second, valorising waste heat arguably integrates the data centre industry with the energy sector. Yet, this integration does not happen by generating truly green energy. Even if the data industry claims to be an active agent against global warming that reduces its carbon footprint by creating infrastructural loops of renewable heat, none of the approaches discussed in this article provide an actual alternative to polluting energy *sources* that power data centres with electricity, such as coal. Rather, the data centre industry relies on the existing sources of power available in each specific location, and these can differ substantially.[2] Nor do data centre operators reduce the amount of electricity needed to power a data centre. Instead, the claimed energy efficiency through valorising waste heat translates into economic efficiency for the data centre operators, which decrease their maintenance costs while expanding their sphere of influence, by introducing server waste heat as a competing resource to other forms of recycled waste, such as biomass used for heating. Hence, data centre operators do not offset the environmental problems that the industry generates, but rather reshape the discourse around it. Rather than an image of powerful actors who change our epistemological orientation in the world, the operators of data centres are redefined culturally into providers of desired infrastructures that are needed for a sustainable, fossil-free future. In effect, data production becomes connected with imaginaries of an environmentally responsible global citizenship and illustrates how infrastructures can produce specific citizens (Larkin, 2013; Von Schnitzler, 2008), who have to keep creating data for the improvement of everyone's well-being.

In the context of these developments, there are nevertheless some structural constraints to these shifts in the meaning and value of data that need to be acknowledged.

The convergence between the data centre industry and urban heating infrastructures is dependent on a well developed and broadly used district heating system. In Europe it is the Nordic, Baltic and some Eastern European countries that have more than half of the population heated in this way and serviced by fibre optic internet, making them potentially attractive locations for such approaches. Other European regions, likewise rural areas have limited or no access to district heating, and a much less developed fibre optic connectivity (Euroheat and Power, 2015; European Commission, 2015). This unequal geographical distribution poses limits for where data and heat infrastructures can converge, yet makes certain locations, particularly major cities in the Nordic countries, into potentially more important data and energy nodes in the future.

On the other hand, the possibility to create a distributed data centre depends on the abilities of the data industry to make specific arrangements with major actors in the telecom industry. In order for Qarnot computing to be able to heat homes with computation, it had to enter into a partnership with Orange, a large telecom and fibre optic cable operator in France, which installed dedicated fibre optics in selected buildings on top of existing fibre optic connectivity as a way to secure a reliable and fast link to the Q.rads[i]. Similarly, Bahnhof in Sweden rents dark fibre from the municipal company Stokab and Skanova, a private holding for its own services. Therewith, the potential for making distributed data and heating infrastructure is dependent on the telecom switching and backbone industry which determines its outreach and speed of expansion.

These dependencies ultimately illuminate the importance of the geographical locations where the data processing industry becomes an energy provider, and how they contribute to sustain and reproduce existing digital divides and politics of access. The new generation of energy efficient data centres seem to be the ones located in the colder climate zones of the fibre-abundant global North, pushing the need for further investment in rapid and reliable connections there, while solidifying the rural network edge as a periphery and a host of larger yet less efficient, slower and polluting data processing facilities.

The present analysis suggests that there are a range of issues arising from the currently decentralising and converging data centre infrastructures which require further critical analysis as their operators experiment with diverse schemes to commodify waste heat. This article is a modest attempt to start such a discussion and hopes to prompt further critical engagement with the expanding infrastructures of big data as they get integrated into realms beyond the online.

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Notes

1. Data from email exchange with Qarnot computing, July 2016.
2. It should be noted that the energy sources that power the data centre infrastructures differ across Europe. Particularly in the Nordic countries, as well as Malta, Latvia, Lithuania and Portugal, energy is generated mostly from renewable sources. In other countries, such as Estonia, Poland and Greece, solid fuels are most prevalent (Eurostat, 2016). This means that the energy sources powering data centre infrastructures in Europe generally vary from country to country. In the examples discussed here, the primary energy sources are nuclear and hydropower.

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