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SMART THERMOSTATS AND THE ALGORITHMIC CONTROL OF THERMAL COMFORT

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Smart temperatures

Smart speakers, doorbells with facial recognition, personal smart entertainment systems, digital home assistants, smart lighting and many more devices have all become part of a growing landscape of media that add a layer of 'local intelligence' (Thrift and French, 2002) to domestic space and infrastructure. Smart thermostats are a further example of such devices. They are gaining popularity in everyday life through Big Tech's 'smart home' systems such as Google Nest and Apple's HomeKit, and are available in many versions, sold by several companies. They promise to provide users with increased temperature control and thermal comfort at home, while at the same time-saving energy. The Google Nest Learning Thermostat, for example, is presented as a device that 'learns the temperatures that you like when you're at home and then programs itself. It automatically turns down the heating when you're away to help save energy' (Google Nest Help, n.d.). Such marketing promises activate an old techno-utopian ideal of providing users with digital servants who can care for their needs and desires in optimal, individualised and pre-emptive ways (Suchman, 2007: 219). In practice, they remake the spaces of everyday life into programmable environments and try to configure domestic life and infrastructure to perform optimally through information and sensing (Gabrys, 2014).

As consumers buy smart thermostats and try to make their homes more 'intelligent', energy utilities in many countries have discovered the potential of 'moving beyond the metre' and are redefining their relations with energy customers. 'Smart home' technologies – with smart thermostats as part of this ecology of devices – have made it possible for utilities to offer a broader range of services (e.g. real-time energy-consumption feedback) and to harness the flexibility that households have to shift some of their electricity or heat use during the day to optimise their own energy system. Despite such attempts to steer energy use patterns in homes, users

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are promised that their freedom to control their thermal home environment will not be compromised. Against this backdrop, some public and private energy companies have started to experiment with adding automated decision-making (ADM) to smart thermostats to both track users' thermal preferences and everyday energy-use routines, take decisions about controlling their thermal comfort in real time and ensuring cost-efficient operation of the local energy grid.

In this chapter, we discuss how energy companies and tech start-ups are experimenting with embedding ADM systems into smart thermostats, simultaneously testing and reshaping relations between private homes, energy infrastructure providers and data-driven companies. Our approach is inspired by the recent call (Marres and Stark, 2020) within science and technology studies (STS) to re-invigorate the experiment as an empirical and theoretical lens that can help us to understand how testing operates on and reshapes social life. As Marres and Stark (2020: 433) argue, experiments in digitally mediated contexts are not done *in* social environments but rather 'the social environment is itself the object of testing'. Drawing on this perspective, we suggest that ADM should be seen not as a process of delegating decisions from humans to machines but as a mediating algorithmic logic that, through experiments, binds together, mediates and transforms relations between multiple economies and 'social worlds' brought together by a common concern with temperatures. We develop this argument in the empirical context of an experimental project, Thermo-S, that took place in Sweden in 2019–2020. The next section presents the experiment and our approach in more detail.

Experimenting with ADM

Thermo-S was the name of an experiment that took place in a popular Swedish mountain resort, Åre, between 2018 and 2021. Our knowledge of it came through media publicity, where it was described as 'a unique self-learning project' that was 'first in the world to digitalise district heating' (Jämtkraft, 2018) and introduce ADM as a service to energy companies and homeowners. The experiment was realised as a partnership between a local, publicly owned district heating (DH) company, Jämtkraft, and a Swedish producer of smart thermostats, Ngenic. Participants in the experiment were provided with smart thermostats and promised advanced thermal control of their homes, while at the same time an ADM system at the backend of the thermostat would incrementally steer home temperature according to the needs of the energy company to optimise its DH infrastructure. Temperatures were controlled by algorithms that used data and sensors installed in participants' homes to demonstrate the efficiency of automatic steering. The smart thermostats are commercially available, but within Thermo-S they were provided free of charge to 21 volunteers and were installed in 37 buildings, including a few hotels, apartments and houses. It was intended that the experiment, if successful, would pave the way for a large-scale roll out of these devices and algorithmic steering of temperatures in other DH systems owned by the energy company.

Thermo-S reflects contemporary visions about the creation of 'smart', programmable environments, infrastructures and homes, taking shape today through sociotechnical experiments in 'real-world' settings. As scholars within STS have argued, such experiments operate at multiple scales (Ansell and Bartenberger, 2016) and are public demonstrations of the ideas. They are intended to persuade selected audiences, even when their outcomes are largely uncertain (Laurent, 2016). In such experiments, computational means are used to modify society (Marres, 2020) and to turn social life itself into an object of observation, quantification and testing by a wide variety of actors (Engels et al., 2019; Marres and Stark, 2020). Marres and Stark (2020) have more recently suggested that the long-standing concern of STS with sociotechnical experiments should be extended to conceptualise such experiments not as settings within which something is to be confirmed, proved or established as a 'fact' but as generative environments through which new relations between actors are established, alongside new modalities of knowing, valuing and acting.

Drawing on this perspective, we regard ADM in the context of the Thermo-S experiment as generative of a new sociotechnical environment in which new relations between households, the energy company and the thermostat provider are being 'figured out' and constituted. We were not part of Thermo-S but studied it at the end of the experiment with the aim to understand how it had unfolded in everyday life, what experiences, conflicts and frictions emerged in relation to the ADM steering, and what broader implications of the experiment arose. We analyse in this chapter how the experiment was understood in the distinct 'social worlds', economies of value and social practices to which the actors gathered in the experiment belonged, that is home dwellers, an energy provider and a start-up company producing IoT solutions and data services. While the aim of the experiment was to determine whether an ADM system for algorithmic temperature steering could bind together all three social worlds in a way that was 'optimal' to each of them, we analyse here how it functioned and how it was valued differently by each of the actors.

Methodologically, we draw on a combination of interviews and digital methods. We interviewed two engineers in charge of the experiment, one from Jämtkraft and one from Ngenic, in early 2021. We approached all 21 building owners and interviewed six of them in the spring of 2021, to obtain their perspectives. Two of them owned multi-tenant buildings that are usually rented out to tourists, and the rest were single-family homeowners. In addition, we performed a version of the walkthrough method (Light et al., 2018) on the app that the participants received and consulted marketing and press materials available online.

We discuss in the following sections the three realms and their different modes of valuing and relating to the experiment separately and analyse the frictions and new relations that arose.

Thermal comfort in the home

The setting for testing the ADM algorithm in the Thermo-S experiment was the home and the thermal comfort it provides to its dwellers. Comfort and energy use in homes have attracted the attention of social science research for a long time (see, e.g. Shove, 2003; Gram-Hanssen, 2010). In this context, indoor temperatures have always implicitly raised questions of social control and transformation (Beregow, 2019). The politics of control and manipulation of thermal systems have historically been associated with the engineering of technical solutions that provide pleasure and entertainment in everyday life and a sense of modernity and progress (Ackermann, 2010). As Cooper (2002) has shown, the installation of air conditioning in American homes has also led to the redesign of houses and changes in the standard of buildings and in cultural expectations of everyday life in artificially temperate environments. These expectations were shaped by engineering visions and practices while users were generally assigned a passive role in these developments. This changed dramatically with the advent of devices marketed through the discourse of 'smart homes', which emphasised the 'activeness' of users and their capacity to automatically control the home and its indoor environment – a user imaginary that was succinctly labelled 'resource man' by Strengers (2013).

Imaginaries of smartness and temperature control also played an important role in the Thermo-S experiment. In order for experiments to function, social settings must be 'instrumented' and curated. Such curation requires mediation, a materialising practice through which devices, apps, buttons and links are inserted into social environments, with the aim of rendering them representable and liable for actionable, establishing connections between a test 'field' and a 'laboratory' (Marres and Stark, 2020). As part of instrumenting the ADM intervention, Thermo-S required that the participants install smart thermostats in their homes, as well as an app developed by Ngenic. The participants were asked to activate and use these devices through which their thermal comfort would be algorithmically steered.

The Ngenic smart thermostat was presented to participants as working to improve the thermal comfort in the home. The system's built-in 'intelligence' would track and predict individual comfort needs; it would 'learn' temperature preferences at different times of the day, keep participants informed about the current state of their indoor environment, and give them control, also remotely. The latter function allowed them to turn on or off the heating at home while sitting in the train or car on their way home. Marketing materials suggested that the devices were 'extra brains for heating your house', 'self-learning systems that help you save energy and money – so that you can do something else'. Ngenic promised to make users into 'climate heroes', while ensuring an individualised and increased sense of comfort, and a consistent indoor temperature (Ngenic, n.d.).

In the Thermo-S experiment, the degree of agency of participants over their thermal comfort was negotiated through the app that came with the smart thermostats. Participants must first activate the app, after which they were allowed to express their desires for a comfortable thermal environment at home. While installing the app, the participants consented to 'terms of service', through which they delegated the control of their heating system to Ngenic's ADM system. These terms of service also assigned responsibilities – to Ngenic to algorithmically steer and track energy use in the home in a way that it perceived as efficient, and to participants to support the system by ensuring that the smart thermostats were always connected to the internet. Crucially, the terms of service suggested that the efficiency of steering was based not only on users' preferences but also on 'external demands':

> Ngenic has the right to steer based on external demands, for example but not limited to grid capacity reserves, balancing power in order to enable an efficient energy use and energy system. Such steering is limited so that the users' comfort is not influenced in a meaningful way. Ngenic can occasionally extend the steering and should inform then the user of eventual discomfort.
> *(Ngenic – Terms of Service, n.d.)*

While the language of intelligence sought to create a sense of empowerment of the users and suggest a sense of control, what participants in Thermo-S were actually doing was to invite a third party to track their thermal preferences and control them according to its own ideas of efficiency.

Unsurprisingly, the user interface of the app did not allow for much control – the main thing that users were encouraged to set was the temperature between 12 and 24 degrees, using the app as a remote control. They were also shown simple charts that presented statistics over the change of daily indoor and outdoor temperature. To make this rather limited form of user control seem more dynamic and compelling, the app applauded participants when they changed the desired temperature by 0.5 degrees or more, with acclamations such as 'Woop, Woop! Your changes have been saved!', assuring them that the system nevertheless works *for them*. However, participants were rather passive in practice, and few changed any settings. One said: 'I never change or touch anything, I have set it up where I want to have the device in the house. I have set it at 21, or 20.5 degrees. And it works'. Another participant reflected more on how the algorithmic control behind the app worked, but overall was also rather passive:

> Well, I never change anything. The thermostats stay where they are, and the app stays too. But what I wonder about sometimes is whether it matters at all what I do with the thermostats at home. It shouldn't matter whether we control the thermostats or not, but I feel that it does matter.

Some participants were only checking the temperatures displayed on the app screen. One explained: 'I use the app mostly to look at the temperature outside, as I know that it is correct'. Others did not find much meaning in looking at the temperature statistics at all: 'No, no, I haven't followed any charts. I see that there are charts. But I don't sit and watch them'. Others appreciated the possibility to set the temperature of their houses remotely:

> It is nice that while we live in Stockholm, we can open the app every now and then and check the temperature, that it stays where it should be. We plan then to travel up to Åre on the 7th or 8th. And I have set the app so that it

> should be warm in the house a day before. And then you can actually see that it starts [heating up] even maybe a day before that.

Using the app as a remote control gave some users the feeling that they were in control of their thermal environment, and that they could reduce their heating costs. But, as Benson-Allott (2015) points out, while remote controls are the most common media device of the 21st century, they are both a technology and a cultural fantasy. They give a 'push-button sovereignty' – a sense of control over our personal media technologies that builds upon historically specific ideas about how users should interact with the industries 'behind' the remote, while at the same time limiting sovereignty over these devices. In the Thermo-S experiment, participants could scroll and select temperatures remotely as much as they wished, but the DH company and the new ADM algorithms experimented and controlled their heating according to their own rationalities and needs. Although the smart thermostats seemed to shift control and action to participants, independence in temperature control remained a cultural fantasy, while the ADM system also let in others to occupy the virtual control room of the home, as discussed later.

Optimising infrastructures

While from the perspective of the participants, the smart thermostat from Ngenic gives advanced control over the thermal environment at home, this picture looks very different when seen through the eyes of the energy company that is in charge of providing DH to houses. Its concern is the limited capacity of the DH grid and the need to cover peaks in demand with heat from fossil fuels. While the mountain resort has grown, and cultural expectations for heat delivery at particular times have evolved, the energy company has been compelled to become innovative in order to keep up with demand while at the same time generating profit.

Demand-side management by the energy company can be achieved in several ways. In the electricity grid, time-dependent tariffs can be offered to users, making energy more expensive at certain times of the day. Peak periods are, for example, in the morning when many use warm water for showering, and in the afternoon when saunas are turned on for 'after-ski'. Another approach is to allow the energy company to switch off certain devices, such as heat pumps, for brief periods when demand is high. Experimenting with ADM via the smart thermostats in Thermo-S allowed the energy company to track and control users, to borrow and redistribute heat between their homes via the DH system and to predict heat demands from earlier data without changing the physical infrastructure. In advance of an expected peak (such as the period of early morning showers), the room temperature in the homes with the Ngenic thermostat could be raised slightly, so that the temperature in bathrooms and other rooms could subsequently be lowered during the peak period, reducing the overall need for the utility to produce heat.

By avoiding such fluctuations, the DH system is shaped to operate under an economic rationality of 'optimal' infrastructure use, while the ADM algorithms also carry the promise for the energy company to avoid investing in new production plants and larger pipes, reducing the need to burn oil. As an engineer from Jämtkraft explained:

> We want to keep an eye on our client from a production perspective and from the perspective of the user's heat usage patterns, in order to predict how we should run our heat furnaces in order to make an optimal and stable network.

Keeping an eye on citizens also meant algorithmic control of their heating and their experience of thermal comfort. This rationality in the Thermo-S experiment required that 'users' be redefined. For a long time, households connected to DH in Sweden have been conceived as 'offloading heat points' by the utilities, without the possibility to significantly influence heat use in homes: 'Our infrastructure was too rigid to react to or guide user behaviour', a Jämtkraft engineer admitted. Ngenic's smart thermostats allowed the DH utility to redefine users into 'active nodes', whose thermal comfort could be steered towards particular aims of the utility: 'Steering the nodes produces much higher cost efficiency, because you can do much more with your existing infrastructure, bypassing local and global limitations in the system', one Ngenic engineer explained, on behalf of the energy company Jämtkraft. Still, this new system of control required the acceptance and cooperation of users. Ngenic defined this cooperation to the utility in the following way:

> And, here we should remember that in order for the client to consider this meaningful, they need to get something out of it. But here I want to be a bit like JF Kennedy. Don't ask what the energy company can do for you, ask what you can do for the energy company. We are trying to make the energy clients into good energy-system citizens.

This quote gives an idea of the logic employed by the utility when controlling the thermal environment in the home via the ADM system and the smart thermostats. This logic differed from the logic presented to participants in the experiment – of full control and, in a sense, liberation from the material constraints and 'normal' logic of the DH infrastructure. Households should, according to this logic, become optimal and efficient agents who serve the network. In other words, while homeowners are promised the use of an algorithmic 'servant' to care for their thermal comfort at home whenever and from wherever they wish, the algorithmic 'servant' is, in turn, expected to enable the users to work for the utility's interests.

The driving force here is the technical and economic optimisation of the energy system run by the utility, and this is achieved by knowing the user as well as possible (predicting demand), and overriding the temperature control in homes in a way that should be hardly perceptible to dwellers. Households give the utility access to the heating system at home and receive in return the promise of cleaner energy, free (or discounted) smart thermostats, and a guarantee that the temperature interventions by the utility will be imperceptible and will not compromise the sense of thermal home comfort. And if this is not enough, the user should at least try to be a 'good citizen', as the aforementioned quote requests, and yield to the demands of the energy company. The smart thermostat arrangement thus also incorporates a decision about the distribution of economic benefits: while shaving peaks saves costs for the utility and generates income for Ngenic, the user is asked to collaborate for the public good.

Trading data

The smart thermostats also connect the thermal comfort and economy of the home to a third realm, an economy of data. Data practices, automation and prediction have always played a vital role in the infrastructures of energy provision, as they have allowed utilities to craft a sense of seamlessness and uninterrupted provision of energy (Cohn, 2017). However, these data have until now been the domain solely of energy companies. ADM experiments such as Thermo-S allow companies from the data economy to insert themselves as an 'obligatory passage point' between energy companies and homeowners, gaining positions as data brokers. Such companies have only recently entered the 'world of energy', but they are changing the way energy utilities operate and how economic value is extracted from energy customers. As an Ngenic engineer argued,

> With our 25,000 clients today, we collect more data from them than all energy companies in Sweden do . . . and, new actors like us can look at the data with fresh eyes and build a completely new architecture.

Looking with 'fresh eyes' on data allows Ngenic to articulate it as a commodity and provide it as a service that is sold simultaneously to several markets, where homeowners, energy companies and data markets themselves are different 'clients': 'The source of data is the same. But we can use this data to provide a range of different services, both towards homeowners, and towards energy companies', Ngenic's engineer clarified. These services have been developed and tested as part of experiments such as Thermo-S that offer Ngenic a laboratory for trying different modes of using data and algorithmic steering in 'real-life' settings and fine tuning them towards different markets: 'When we don't guide the users towards the grid's purpose, then we guide them to optimize the building and the comfort in it. It is based on the same data. But it is just another service'.

In this new architecture, ADM itself becomes a commodity sold as a service, and utilities such as Jämtkraft become users to whom data from their own clients can be sold: 'They [the utility companies] have access to all this data. But we format them in a way that makes them useful for those running the engines, and for the distribution infrastructure', Ngenic's engineer explains.

Ngenic must ensure that users agree to share their data for multiple uses, to allow the company to carry out this formatting and create the new architecture. It achieves this by framing the sharing as an act of good citizenship. The company tells homeowners: 'Sharing your data makes you a good citizen. We will do the rest of the job. The only thing you need to do [as a user] is to say that this is OK'. The households are given the smart thermostat and in return they give away information about their energy use and indoor climate. This can then be processed by companies such as Ngenic to predict aggregate demand for the utility, or may be used by the ADM system to improve the quality of thermal services for homes.

Such data get also connected to the existing digital markets operated by data giants. For instance, the terms of use of the thermostats state that Ngenic's services share data with Google and Facebook for marketing and analysis and not just with energy companies (Ngenic – Data Protection, n.d.). By joining the Thermo-S experiment, users do not need to buy Google Nest: their data are seamlessly integrated as another stream into the digital infrastructures part of the platform economy (Gerlitz and Helmond, 2013).

Such an integration of users into global data markets is, however, never entirely smooth. Algorithms, and ADM systems, have obligations, and one of these is to produce satisfaction (Gillespie, 2014). Ngenic's algorithmic control is no exception – the premise of the smart thermostats and the data services they enable is to bring satisfaction to all involved parties in their distinct social worlds. However, these social worlds have contradicting understandings of the value of controlling temperatures – while users are promised an increase in their control of thermal comfort, the energy utility is promised the ability to control the users' flow of heat to a greater extent. This results in 'a conflict between the individual clients' interests and those of the system', as Ngenic puts it, and this is a conflict that the ADM system must accommodate. To resolve it, the algorithms in the ADM system are trained to weigh these different interests against each other, making sure that the satisfaction of the 'system' in terms of cost and energy efficiency is cared for, while 'No client should notice in terms of their thermal comfort when we exert control', Ngenic explains. Through this approach, using the results of the experiment to tune the ADM system determines power relations between users, the energy utility and Ngenic and inscribes particular hierarchies and priorities into the algorithms.

The value for Ngenic of experimenting with ADM in the Thermo-S project is then partly to see what can be done with the data in terms of packaging it as a service, and partly to test the socially and sensorially acceptable limits of controlling thermal comfort algorithmically, in order to make such multiple data service provision possible and seamless.

ADM and the algorithmic control of temperatures

The Thermo-S experiment connected and simultaneously managed three realms of actors and concerns. It created an environment for the thermal control of the home, where participants obtained enhanced possibilities to visualise and influence their in-house environment through a data platform on an app running on their phones. Such attempts to control thermal environments in buildings are not new. However, the tools through which they are implemented – thermostats, real-time data tracking and analysis, and ADM – convert mundane, everyday needs and desires about temperature regulation into an arena of algorithmic mediation where energy utilities, Big Tech and small tech actors try to capture new data markets and value.

The promise of better control and increased thermal comfort is a crucial argument for homeowners to participate in this experiment, although this promise is accompanied by an additional one: that these thermostats will help to run the whole DH system more efficiently and in an environmentally friendly manner. This promise links the comfort economy of the home to two additional realms of control that are driven by fundamentally different sets of values, interests and strategies: the social world of energy utilities with an interest in gaining control of the energy use in homes and managing this energy use in a way that helps to optimise the utility's energy system both economically and technically; the world of data and IT companies, who gain access to household energy use data that can, in turn, serve as the basis for new kinds of commercial service.

The achievement of the ADM system is to mediate between these three social realms and manage trade-offs in a way that sufficiently satisfies the different actors involved. On the one hand, the algorithm gives more user control, while, on the other hand, it reduces user control by allowing the energy company to override user temperature settings for the purpose of load management for as long as it remains hardly perceptible to the user. In reality, users never fully control the temperatures in their homes: the best they can hope for is that the mediated representations of temperature that they set in the app actually provoke some action, and that they sense a difference.

Moreover, the smart device enrols the household in a data economy interested in keeping users engaged on apps and generating data that are subsequently used in commercial services. The ADM system thus creates a new space for decision-making that did not exist before. While traditional thermal control systems are steered by a specific target temperature, decision-making in the Thermo-S system is much more complex and is driven also by load predictions (which in turn depend on data from other users), grid capacity and various economic considerations.

The decision-making algorithm of the ADM system is configured in a way that defines social relations between the actors involved (homes, utilities, data-processing companies) in terms of social power and economic gains. This experiment has tested the feasibility of this social and economic configuration and the compliance of users much more than it tested the technology: How much temperature variation do users accept, if they know it is of social and environmental benefit? How much data sharing do they tolerate? How large is the benefit of the data-based services provided to the utility?

Conclusions

The broader question that our analysis poses is, to what extent did the experiment make the 'reconfiguration of society' at stake here more transparent and politically negotiable. Sticking with Laurent's (2016) argument that an important function of an experiment is to create and convince publics, and that experiments are always at least partly uncertain and have an element of surprise, we can observe in our empirical case that these elements are unevenly distributed across the different actor worlds brought together by the smart thermostat. As Nadaï and Labussiére (2018) point out, experiments often address different publics in different arenas simultaneously. The DH users as one of the publics addressed in this experiment are meant to be convinced that this experiment delivers better thermal comfort and control to the home, while there is at the same time no risk or uncertainty involved for the user. For the corporate publics of Jämtkraft and Ngenic, this experiment is rather a proof of concept which not only aims to demonstrate the technical feasibility of the system but also its ability to 'pacify' end-users, keep them satisfied and enrol them into this new configuration. At the same time, the experiment is aimed at a wider national public to which it demonstrates the innovativeness and boldness of Jämtkraft in taking first steps towards a new kind of energy system ('first digitalised district heating system in the world'). Despite these different publics and the narratives developed for them in the experiment, the new social and economic relations created through such experiments do not get much attention. The additional economic value created by the flexibility to manage heat loads and by the data syphoned off and used in commercial products appear to remain purely with Jämtkraft and Ngenic. Users give away both their 'flexibility capital' (Fjellså et al., 2021) and their data without getting much influence on their further use.

Questions can also be asked whether such systems reduce energy consumption and greenhouse gas emissions (as claimed by Jämtkraft) or whether the new control possibilities increase heat consumption by the need to rely, for instance, on computation taking place in data centres. Instead of laying bare the shifting economic and power relations between the actors of the new smart energy system tested in this experiment, the ADM algorithm renders all these relations invisible, by creating an illusion of autonomous control in homes while at the same time configuring decision processes in ways that benefit the commercial interests of the energy suppliers and data companies that provide new data services. Customers who are not connected to a smart device can always change the setting of the radiators manually to save energy, but passing control to the energy company may, paradoxically, lead to the consumer taking fewer active choices and forgetting that active choices are possible.

The broader relevance of such experiments that examine the algorithmic mediation between infrastructure providers, data-driven tech companies and infrastructure users should not be underestimated. While energy infrastructures in the past were driven by an ideal of providing universal service, capacity reserves and a network expansion that followed growing demand, this has been increasingly replaced by attempts to handle capacity problems by 'managing users', by collecting and processing data about their behaviour, and the subsequent control of their infrastructure use by economic incentives, appeals to citizenship, and incremental manipulation of the infrastructure-based services they receive. These new arrangements apply to all kinds of infrastructure, such as heat and electricity networks, electric vehicle charging facilities and traffic management. What is tested here is indeed a 'reconfiguration of society', and the analysis of such experiments as we have attempted in this chapter may help to re-politicise questions of the distribution of social power and economic benefits, privacy and data sovereignty, transparency of control, the socially uneven access to new infrastructure services, and the individualisation of environmental responsibility.

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