Traversing the Infrastructures of Digital Life

Hannah Knox

In this chapter I turn my attention to the infrastructural qualities inherent to the experience living with contemporary digital technologies. Digital technologies from smartphones to bitcoin, rely on infrastructural networks - from undersea cables, to the hundreds of communications satellites that orbit the earth, radio communications masts, fibre-optic cables, local Wi-Fi transmitters, and mobile data communications standards. Communications protocols and programming languages also infra-structure technological devices, making the inter-operability of particular platforms possible and creating the basis for contemporary ways of communicating and socialising. Moreover, not only do digital devices rely on communications infrastructures, but infrastructures of other kinds from energy grids to global logistics are undergoing their own processes of digitisation. Digital infrastructure includes then, not only the wires and cables that support mobile and computer communication but also the integration of sensors, databases of measurements, and real-time data analytics into buildings, motorways, ticketing services, fast food delivery, taxi services and more. Digital infrastructures in one, other or both of these senses are now an inherent part of contemporary life for most people in the world and their effects on the reorganisation of social life have been profound. These digital infrastructures have provided the grounds for structural transformations in social relations, for what it is possible to know, for communication, mobility, kinship, and access to resources.

Work to understand the far-reaching social dynamics of digital infrastructures has been very much an interdisciplinary undertaking, involving not only anthropologists

but also scholars from media studies, art and design, science and technology studies, philosophy, geography, sociology and computer science. As we will see, one of the characteristics of studies of digital infrastructures is that understanding their political and cultural aspects often require a blurring of disciplinary theories and methods: social scientists find themselves becoming proto-engineers; computer scientists become political theorists; and media studies scholars to turn from the communicative qualities of texts to the chemicals, substances and flows that enable information to flow along fibre-optic cables or be housed in Arctic data centres. Owned and controlled by a heady mix of corporations, states, individuals and communities, digital infrastructures are often highly opaque and difficult to trace demanding a variety of disciplinary approaches to uncover different aspects of their reality. Indeed, understanding digital infrastructures is often said to pose such a challenge to disciplinary boundaries that in some cases it has even led to proposals to create new disciplinary formations more appropriate to the study of the human in the context of digital life[1].

In order to traverse these interdisciplinary debates and discussions, this chapter begins with a brief overview of recent work on digital infrastructures that cross-cuts these disciplinary boundaries. I group these discussions under four sub-headings: The Network Society, The Logic and Form of Digital Infrastructure, Re-Materialising Digital Life, and Coding Inequality. Key texts and thinkers in each of these discussions are introduced and the descriptions of the social effects of digital

[1] For example, the emergence of disciplinary groupings concerned with Social Data Science such as SODAS at the University of Copenhagen (wwwhttps://sodas.ku.dk/), or Genevieve Bell's current work to "a new applied science for understanding our future humanness" (https://www.afr.com/brand/boss/genevieve-bell-investigates-how-humanity-can-prosper-in-a-datadriven-world-20171011-gyzau3)

infrastructures under each of these headings is explored. I then move on in the second half of the chapter to two case studies through which I consider, in more depth, what an anthropological approach to digital infrastructures might look like. The two cases I have chosen highlight the opacity of digital infrastructures and the challenges that this poses to studying them. The first case study looks at engagements with smart grids to show how the un-boxing of digital infrastructure points to the ecological qualities of infrastructural relations. In the second case study I unpack this ecological relationality further by looking at the information infrastructures of climate science and tracing some of their effects. Here I explore how the globally distributed systems of data analysis that constitute climate science come to create a phenomena that challenges a networked and information-communication based understanding of knowledge and its transmission, replacing it with a more modulated and emergent understanding of relations between people, data and things.

PART 1 – Approaches to Digital Infrastructures

The Network Society

It is now over twenty years since Manuel Castells published his seminal volume *The Rise of the Network Society* (Castells 1996b). Here Castells outlined what he saw as the profound transformative effects of new networked information technologies on social, political and economic life. Following in the footsteps of earlier theorists, from Daniel Bell and his prescient 1970s description of the Information Age (Bell 1973) to Mark Poster's exploration of the 'mode' of information (1990), Bauman's Liquid Modernity to Paul Virilio's Speed and Politics (Virilio 1986), Castells' volume gave

empirical meat to the philosophical bones of media theory to argue that global networks of computation were heralding a new 'space of flows' whereby political and social inequality was being reorganised around the question of who could tap into and control those flows and who could not. Castells' work pushed back against more celebratory accounts of the benefits of the knowledge economy for post-industrial nations which had lauded the boundary-crossing communicative potential of digital technologies and their ability to create new forms of economic wealth by generating new service and creative sector jobs (Florida 2002, Negroponte 1995). In contrast, Castells highlighted the more deleterious effects of a network society for women, the poor, and for non-industrial economies (Castells 1996a).

Since the publication of this volume, others have elaborated on Castells' central observation that life in the space of flows is shaped by new trajectories of power and inequality. Some have developed his work on the digital divide with further empirical detail of precisely how digital networks exclude some whilst including others (Everett 2009, Norris 2001). Others have turned to the dark side of the digital industries themselves to explore the everyday labour that sustains the new economy (English-Lueck 2002, Gershon 2017, Ross 2003). Luc Boltanski and Eve Chiapello's New Spirit of Capitalism (2005) is perhaps the most well known exploration of the pernicious and exploitative effects of neoliberal principles of autonomy, freedom and creativity that have informed the organisation of digital workplaces that drive the network society, whilst Shoshana Zuboff's new book *The Age of Surveillance Capitalism* (Zuboff 2019) provides a new and damning diagnosis of the new lines of power established by platforms which deploy consumer analytics to describe and shape human being in new and disturbing ways.

The Logic and Form of Digital Infrastructure

If digital technologies have been shown to have structuring effects then this has also begged the question: why? Structural accounts describe such effects in political economic terms, focusing on access to resources, ability to generate income, levels of cultural participation and work/life balance. However they are often silent on the more fine-grained detail of the role of cultural beliefs and social practices in shaping how and why these effects emerge and how they are sustained. If the digital economy enacts an infrastructural violence on large numbers on people (Rodgers and O Neill 2012), then what drives the desire for more connectivity, more devices, more analytics? Dissatisfied with the idea that digital infrastructures are expressedly designed to have nefarious effects, or that they are the straightforward manifestation of a rapacious logic of neoliberalism, other scholars have turned their attention to unravelling the hidden logical assumptions built into digital infrastructures and the way in which these logics produce specific digital media forms and effects.

This work cuts across the tradition of science and technology studies, critical software studies and a post-structural anthropology of technology and knowledge. Adrian Mackenzie for example, has written extensively on the relational ideas built into and extended through digital infrastructures, looking at digital infrastructures as diverse as Wi-Fi, github, DNA sequencing and search engines in ways that highlight how they both enact and create particular relational assumptions about the world (Mackenzie 2006, 2011, 2017, Mackenzie et al. 2016). Mackenzie's work, which builds on a reading of pragmatist and post-structural philosophers like Gilles Deleuze and

William James, surfaces the inbuilt assumptions of hardware and software engineering and brings them into conversation with the relational principles that sociologists deploy in the creation of sociological knowledge. Anthropologists have also been exploring the cultural bases of computational processes such as the cultural ideas inscribed in robotics, automation, AI and algorithms (Castaneda and Suchman Lucy 2005, Lowrie 2018, Maurer This volume, Seaver 2015, Wilf 2013).

In a similar vein, Paul Kockelman's (2013) work on spam filters as sieves also addresses digital infrastructures from the perspective of their logical operation – in this case looking at sieving as an ontological figure that informs and shapes statistical techniques through which spam filters and search engines make their selections. Here we see a shift from a focus on the relational logics or presuppositions of digital infrastructures to a question about the ontological qualities of digital technologies. Considering digital ontologies, and indeed whether it even makes sense to suggest that digital infrastructures have 'ontological' qualities, has been explored in various recent books and journal special issues (Boellstorff and Maurer 2015, Knox and Nafus 2018, Lowrie 2018). A recent collection of Cultural Anthropology's Theorising the Contemporary series, edited by myself and Antonia Walford (Knox and Walford 2016) brought together anthropologists who have been exploring questions of ontology within anthropological theory with those more influenced by media theorists from Frederick Kittler, to Lev Manovich, and Jonathan Sterne who each in their own ways have been interested in the way in which media carry in their design relational logics that both shape the future and carry with them the historical legacy of prior media forms (Kittler 1999, Manovich 2001, Sterne 2012). Attending to the specific relational qualities of media forms, these scholars work across these theoretical

traditions to force analyses of the cultural dimensions of digital infrastructure towards a more hybrid analysis that brings the question of the co-constitutive role that form, matter and the imagination play in constitution of digital architectures, infrastructures and software systems.

Re-Materialising Digital Life

As the infrastructural effects of digital technologies have been shown to be not just the inevitable playing out of a logic of capital, neoliberalism or elite cultural ideas, but a more hybrid kind of techno-cultural emergence, this has opened the way for much more explicit attention to be paid to role that the materiality of digital infrastructures themselves have played in establishing the shape of the space of flows. This has moved analysis from the relational form of digital infrastructures towards questions about the politics of matter. Influenced particularly by discussions in new materialist philosophy[2] and actor-network theory[3], studies of material infrastructures of digital life have highlighted that digital infrastructures are not just mediators for the flow of information to the digitally connected but also enact social political effects through the hidden materiality of their infrastructural form. Like the hybrid studies of digital infrastructure described in the last section, these studies find, in attention to materiality, a way of pushing back against the ephemerality conjured by the language still used to talk about digital infrastructure (the cloud, the web). Moreover these studies on the materiality of digital infrastructures have begun to explore how digital

[2] See for example (Bennett 2010, Coole and Frost 2010, Morton 2013)
[3] A good overviews to this approach include Law and Hassard (1999) and Latour (2005)

life is sustained not only by social imaginaries and cultural norms but also by the embedded histories of particular infrastructures.

In their recent edited volume *Signal Traffic*, media theorists Lisa Parks and Nicole Starosielski bring together a collection of chapters working in this vein, that explore 'physical installations, objects, sites, and processes in detail, analysing industrial transitions, and probing the socio-historical conditions and power relations that give shape to particular infrastructural formations' (Parks and Starosielski 2015: 17). The volume demonstrates first how digital infrastructures are frequently historically associated with prior infrastructural forms. Starosielski's research on the undersea cables that enable the global information economy, demonstrates how fibre optic cables lie along the same trenches as telephone and electrical cables that were laid in the early 20th century, and carry with them something of this geo-political history (Starosielski 2015). In other work roads are shown to be the precursors to electricity and then telephony and fibre optics (Harvey and Knox 2015, Larkin 2013), meanwhile in places that were never connected to electrical grids, or paved highways, the infrastructure of digital technologies more often relies on satellite communications rather than terrestrial cables (Cross 2016). Tracing histories of digital infrastructural uncovers military-industrial relations demonstrating how 'access' to 'the internet' is not a uniform phenomena but is rather the materialisation of specific histories of state-building, globalisation and military control that still inform the development of information infrastructures today.

Another aspect that a focus on the materiality of digital infrastructures highlights is the link between digital technologies and the environment. Vast data centres which

store the information that constitutes the network society are both massive users of energy and also generators of excess heat. To keep servers operating efficiently requires keeping them cool, thus data centres are frequently found in remote locations where high-tech comes into direct contact with other forms of environmental existence (Holt and Vonderau 2015). In the Facebook data centre in Luleå in the North of Sweden, located both in a region of extreme cold and near a hydroelectric dam which provides a close and easy source of electricity, the security requirements of the data centre have led to new forms of environmental enclosure. Here national energy resources are fed into servicing the data-needs of global company, Facebook, meanwhile the local national park has been itself enclosed as part of an attempt to keep people away from the closed walls of the data centre itself (Vonderau 2017). In contrast, data centres in urban settings are now being identified as potential generators of useful heat, transforming the materiality of digital communication into new forms of urban power stations.

If ‘the cloud’ requires data centres in cold places to keep it aloft, so elsewhere in the digital supply chain, environments of other kinds also service the digital economy. Silicon-based processors, lithium batteries and plasma screens depend on minerals which are mined, sold and traded to create their digital effects (Parikka 2011). At the other end of the supply chain, electronic waste poses its own social and environmental problems, including the as-yet-unknown effects of environmental contaminants most of which currently go to landfill, and the informal and undocumented e-waste industry where e-waste produced in Europe, North America and Australasia is transported to developing countries for reprocessing (Gabrys 2011).

From the mining of heavy metals to create digital devices, to the digging of deep sea trenches that make landfall in particular countries and not others, to the reliance of internet infrastructures on water, ice and oil, work on the materiality of the internet has shown that the implications of the digital age for political and economic life extends far beyond their informational qualities.

Coding Inequality

If materiality has generally been taken to mean the hard matter of digital infrastructure – wires, pipes, chemicals, concrete - there is a final aspect of digital infrastructure studies which I want to address which concerns information itself as a kind of material dimension of digital data. Information and matter are often opposed to one another but by recasting information as a form of materiality, what these studies point to is not the physical substance of digital infrastructure, but the very concrete and tangible effects that the ordering of information has on people's lives.

We have known for a long time that infrastructures have the capacity for shaping the social world – probably the most famous example being the Long Island Bridges discussed by Langdon Winner whose infrastructural effect was the whitening of the populations able to use the long island beaches (Winner 1986). It is also now clear that systems of categorisation and classification are powerful world-making technologies both in terms of their capacity to organise (Bowker, Star, and Press 1999) and spatialise (Kitchin and Dodge 2011) social life. Often building on Foucauldian insights into the conduct of conduct, the analysis of digital infrastructures as information infrastructures opens up an understanding of digital

technologies as techniques of governmentality that not only order social relations but constitutes the very categories upon which social scientists rely to describe the social landscape. Virginia Eubanks' recent study of the use of algorithms in the American welfare system describes, for example, how the digitisation of systems which have been developed to assess the eligibility of welfare claimants, has recast the question of deservedness for welfare into a calculative logic (Eubanks 2018). Those excluded from the system and cast out as not worthy of welfare payments have found themselves not only excluded but also ostracised as inappropriately non-participative members of society. Similarly Amade M'Charek's work on the technologies and practices of racial profiling has shown how attempts to informationally order racial differences has the capacity to produce and reinforce racial categories (M'Charek 2013), meanwhile Natasha Dow Schüll's work on gambling de-individualises the figure of the gambler, showing how the category of addiction is the outcome of particular kinds of designed interactions between information displays, architecture, economies and bodies (Schüll 2012).

James Bridle's recent description of the algorithms that are used to organise content on YouTube, provides perhaps one of the most disturbing demonstrations of how the demands of algorithmic processing combined with revenue generation from clicks and views on online ads is constitutive of new, at times absurd, social forms (Bridle 2018). Bridle describes the creation of online content where it is becoming ever harder to easily attribute of authorship of content to human beings. The deployment of informational infrastructures in the age of machine learning and artificial intelligence not only deconstructs the question of human agency but goes even further, posing profound questions about juridical concepts like responsibility (who can be held

responsible for the auto-generation of dark-absurdist content clicked on by the aimless hand of a bored two-year old?), agency (when bots speak to bots) and literacy (what does it mean to 'know' how to proceed in the face of digital infrastructure when even the designers of systems no longer really know how recommendation systems, databases, algorithms and decision-making machines generate their interventions and exclusions?).

It is this issue of the complexity and inherent opacity of digital infrastructures that feed off ever greater repositories of data and ever more sophisticated methods of analysis of that data, that makes this final area of discussion so important. As machine-learning algorithms produce results in ways that arguably no human understands; digital devices produce constant outputs of information too big for any expert or machine to analyse; and the interplay of different systems – some automated, some not - produce non-representational[4] forms that are neither truths nor untruths, we appear to be heading into to what Bridle terms a 'new dark age' where the ability to be able to claim to know what we are dealing with when we interact with infrastructures digital or otherwise is challenged. At the same time as people are cut adrift from any possibility of really understanding the systems that organise us, they are also becoming ever more aware that these digital systems have profoundly divisive effects, and so the desire to know becomes stronger. Here we have gone far beyond the digital divide, a problem essentially of access, into a situation where poverty, racism, nationalism, violence, misogyny, and gross levels of capital accumulation are sustained by and supported by opaque informational infrastructures with powerful real-world effects.

[4] (Thrift 2007)

Rather than trying to resolve infrastructural opacity through either an interdisciplinary attempt to add different kinds of knowledge together, or an attempt to follow the networks of relations through which such infrastructure come into being, in the following two examples I make the case for an anthropological stance which tries to 'stay with the ambiguity'[5] of these infrastructural configurations: that is to allow the opacity of digital systems to become part of the focus of ethnographic work. The complexity of digital infrastructures is recast here not as a barrier to anthropological understanding but is instead treated as a crucial part of people's sense-making practices in the face of the relations made evident by digital infrastructures. Given that anthropology itself is also a practice of sense-making, the case studies also raise questions about the role that digital infrastructures and the data-relations they sustain might play in new kinds of ethnographies of/with digital infrastructure. Ultimately I argue that the seeming ambiguity and opacity of digital infrastructures is less an indication of our failure to trace them in their entirety, and more a result of the ecological form of relationality that digital infrastructures institute as they put people, environments and things into relation in new ways. I explore this through two related examples of digital infrastructure from my own work – the emergence of digital electricity grids; and the digital infrastructure of climate modeling.

PART 2: Life in the Digital Grid

Although 'digital infrastructure' are often taken to mean the infrastructures of digital technologies, already existing infrastructural forms like roads, railways and energy

[5] Paraphrasing Haraway's 'Staying with the Trouble' (Haraway 2016).

systems are also undergoing processes of digitisation. Entangled with the notion of the 'internet of things' where sensors and communications are placed in and on objects in order to make them part of an information infrastructure, material infrastructures are being informationalised and digitally augmented in ways that are producing precisely the kinds of opacities that I touched on above. One area where practices of infrastructural digitisation is proceeding apace is in the monitoring and management of electricity. My first case study therefore concerns an example of an attempt to bring digital capacities into electricity generation, distribution and supply in the UK and Europe.

For most of the 20th century, electricity in Europe and the UK has been predominantly generated by centralised power stations – powered by either coal, gas, hydroelectric dams or nuclear reactors. However as renewable energy technologies such as photovoltaics, wind power, and air-source heat pumps have gradually become more viable, certain qualities of the power generated through these technologies has begun to pose challenges to grid infrastructure.

First the inability to store the source of upon which renewable electricity is generated poses a significant challenge to the management of the electrical grid. Coal, gas, water and even nuclear are substances than can be held in a repository, or 'standing reserve' to be burned, released, or activated at will. For the grid to operate successfully, supply and demand have to be carefully balanced in real time. Whilst demand has been hard to manage, supply has remained in the control of the grid operators. In the UK's nationalised energy system that existed until the early 1990s, power generators would sell their electricity at a fixed price to national grid who

would then provide this electricity to consumers with whom they had a contract. Failure to match up supply and demand could be catastrophic.

The possibility of being able to balance national supply and demand for electricity is central to the logical operation of a national energy grid and was a key impetus for the construction of a national grid in the first place. Having a centralised network to transport electricity from one end of the country to the other at the speed of light enabled differences in the need for electricity, geographies of production, and the contingencies of unreliable equipment to be overcome. Prior to the building of the national grid in the 1920s, over 600 local power stations supplied electricity on local grids operating at different voltages to nearby businesses and homes. Power stations were located close to industrial and urban centres where the users of electricity could be found. Electricity prices in urban areas, where industrial and domestic electricity use balanced each other out, were typically lower than for people living in rural or remote areas whose electricity suppliers did not always have a ready demand for power. With the building of the national grid, it became possible for a standardised electricity tariff to be set for all customers regardless of location. The national grid in the UK was crucial then for creating a national energy public. Wherever people lived in the country, they could expect electricity to be supplied reliably at the moment they needed it, and to pay the same amount for it as people living elsewhere.

One of the major challenges posed by renewable energy sources like wind and solar is that they risk disrupting this system. It is impossible to control when the sun will shine or the wind will blow, so ensuring there is sufficient electricity on the system requires different kinds of technologies and relationships to those demanded by a

national grid powered by a few large generators. Technical answers to this problem include batteries that can store electricity, smart appliances that can turn on and off in response to the needs of the grid and differential pricing to encourage the individuals and businesses to use electricity at different times of day. Whilst these technical challenges and solutions are well known, the social implications of putting renewable energy sources into the grid are less well rehearsed.

I had the opportunity to observe some of the ramifications of smart grid proposas first hand when in 2016 the EU Horizon 2020 Scheme awarded a grant to a consortium of European partners to explore the technical and social feasibility of 'smart' grids under the project heading 'NobelGrid'. The project was concerned in particular with the way in which these changes might open up new opportunities for community-organised energy production, distribution and consumption. The NobelGrid project was an investigation into the technical and social feasibility of grid balancing at a regional or 'community' level. Partners included an energy cooperative in Flanders, a former holiday park in Greece, a district supply operator in Spain, a district supply operator in Italy and both hardware and software engineers. It also included a partner organisation in Manchester, called the Carbon Co-op with whom I spent time doing research.

The Carbon Co-op was set up in 2011 to help reduce the carbon emissions of the city of Manchester. The main focus of their work has been on how to make major improvements to the insulation of people's houses to reduce people's fuel bills. Although this may sound unrelated to the changes in the grid described above, it is very much part of the same story. Most heating in the UK is currently supplied by

fossil fuel based natural gas. If carbon reduction targets are to be met people will have to burn less of this gas. One option is to move from gas heating to electric heating but the demand that this would put on the electricity grid would cripple the grid as it stands. Conservation of energy is therefore an important part of the conversation about a changing electricity grid and one way in which it is hoped that reductions in energy use will be achieved is through the use of smart metering technologies.

Carbon Co-op's involvement in the NobelGrid project was primarily as a test site for smart meters. The carbon co-op were working with their own members, with local housing co-operatives and with a social housing group in order to see how smart grids could support community energy projects and ultimately help achieve reductions in energy use. Smart meters would, it was hoped, be a way for people to get a better grasp on their own energy use, to balance out energy across a community and potentially to be able to sell energy back to the grid on a supply/demand basis.

What emerged from carbon coop's involvement in this project were various unanticipated issues that a digitised energy system was likely to play refiguring the kinds of social collectives that the electricity system would serve. One of the hopes associated with renewable energy technologies is that local sources of electricity generation might be able to provide local communities with a way of gaining control over the creation and use of their own electrical power, an example perhaps of what Alberto Corsín Jiménez has elsewhere termed 'a right to infrastructure' (Jiménez 2014). Smart metering would potentially enable communities to visualise and manage their own power distribution, and to sell the excess collective power back to the grid. Moreover interfaces between micro renewables and technologies like electric vehicles

whose batteries might offer a storage solution for an unstable grid, opened up a further vision of self-sufficient communities using their own green electricity to power sustainable lifestyles. Smart grids seemed to hold the revolutionary potential to pull power back from multinational corporations who currently control electricity generation and supply, returning the control of electricity to 'the people'.

However here engagement with digital infrastructure was less a process of learning from technical experts the possibilities available to communities of well known technological infrastructures, and was more a process of 'infrastructural inversion' (Bowker 1994), whereby the more that the complexities of the digital grid infrastructure began to unravel the more other anticipated questions reared their head. Engaging materially with digital infrastructures served less to reveal their prior invisibility than to refigure them as technical systems that seemed at first to be about one kind of thing (electricity supply and demand) but rapidly shifted into about something completely different (democracy, fairness, rights and responsibilities). Digital infrastructures in their very opacity had, it seemed, the capacity to open up new questions about appropriate sociality.

As people began to tease out elements of the digital electricity grid that might pertain to what they were interested in, their own ways of conceiving of themselves and what they were doing were being transformed. Whilst smart energy seemed initially to provide the promise of greater democratic control through tropes like transparency, openness and freedom, the details of how digitally enabled renewable energy was actually being set up to work to benefit closed communities of people, in fact risked undoing principles of equity and fairness that were originally built into the design of

the grid. If community energy groups were able to generate their own energy, this reintroduced a geographical inequality into the energy infrastructure. Proximity to energy sources like rivers or roofs with the correct aspect, and access to capital, once again risked becoming the determining features of who has access to cheap and reliable electricity.

Perhaps we should not be surprised that when the 'space of flows' becomes part of energy infrastructure, it reproduces the tendency Castells observed several years ago, to create new contours of inequality. What does seem surprising in this case is that it is those groups who have perceived themselves as the most politically radical and driven by principles of ethical living, that find themselves confronted with a system that simultaneously seems to support ambitions for more collective approaches to energy provision, whilst at the same time potentially undermining another collective – that of the national public.

The unfolding implications of the digital infrastructure of the smart grid then, is provoking people to reconsider what forms of social collective might be desirable and even achievable. Changes in one part of the socio-technical-environmental grid, inevitably produced unanticipated knock on effects elsewhere. Here in the discursive interstices riven open by the development of digital infrastructures, the national public is confronted by a digital agora that blurs boundaries between customers served by markets, communities pursuing collective life, cities interested in digitally enabled forms of devolved government, states appealing to a weakening national public and a global humanity that is challenged by climate change.

It is this last issue – the challenge of global climate change – that I want to end this first example with. For whilst smart grids could be understood as an extension of the problem of the network society – a question of how to create more effective, open and transparent communications between parts of a distributed network – they are also a technological solution to a problem whose systemic quality exceeds the problem of the network and bleeds into considerations of ecological relations. This is both in terms of literal ecological relations – how to engage the power of wind, water, tides, sun, bacterial digestion, crops and algae into the provision of electrical power – and an ecological mode of understanding of socio/techincal relations that acknowledges the modulating, shifting, unfolding qualities of assemblages of people, numbers, practices, lifestyles, media images, conspiracy theories and energy sources. The ecological relationality of digital infrastructures is rarely dwelt upon, but this is an aspect of digital relations which anthropology has much to offer and which digital anthropology would do well to pursue. Anthropologists have a long history of analysing and understanding the unfolding interrelations between people and environments – from Gregory Bateson's enigmatic Steps to an Ecology of Mind to Tim Ingold's programmatic agenda for an anthropology of process and flow. Not usually seen as key references for digital anthropologists, these ecological understandings of socio-material relations offer, I suggest, an important resource for understanding the kinds of relations that contemporary digital infrastructures are producing. To explore this further, my second example of digital infrastructure turns directly to a case where digital technologies have made newly explicit entangled ecological relations that include both people, substances and things: the role of digital infrastructure in constituting the science of climate change.

Living with Climate Models

In September 2017 a paper was published in the journal *Nature Geoscienc*e which made the argument that there seemed to be slightly more chance than previously thought that the Paris Climate Agreement to limit global warming to between 1.5°C and 2°C was geophysically possible. A press release was circulated by *Nature* which was picked up and discussed in a news briefing organised by the Science Media Centre. The news briefing was attended both by two of the paper's authors and by journalists from 10 news outlets. The article's findings were then reported by several news channels including BBC News online, Buzzfeed, the Mail Online the Daily Telegraph and the Sun newspapers, some coming with misleading headlines and op eds that reinterpreted the research paper as evidence as a claim not that 'according to our models if we do everything humanly possible to reduce greenhouse gas emissions the 1.5˚C target is still theoretically possible.' but 'climate models are wrong' and that climate change is 'not as bad as we thought'.

The publication of the academic paper and its subsequent reporting caused something of a furore among those concerned with how best to communicate climate science. Coming hot on the heels of a series of devastating hurricanes in the Caribbean and Florida, the paper seemed to add grist to the mill of climate deniers that were keen to discount the effects of climate change in these recent weather events. But, people asked, was this reason enough to suggest that the academic paper itself should not have been published? Did the misinterpretation of the paper's message lie with its authors who should have been clearer about the overall message to be taken from the technical findings they outlined? Should university media communications

departments have anticipated how the paper would have been seen and deployed some kind of ‘damage limitation’? Should the journal have put out a different press release? Should the Science Media Centre have managed their briefing better? Or was the variety of interpretations put forward in the press actually a healthy sign of democratic debate? At least, some said, climate science was being talked about at all. Perhaps it didn’t matter if a few extreme columnists jumped on the ‘uncertainty’ inherent to scientific modelling techniques to bring down the veracity of climate science as a whole.

A perennial challenge facing those aiming to communicate the science of climate change to a general public has been how to translate the ‘vast machine’ of multi-disciplinary, data-driven, statistical analysis that is climate science into a form that can carry into people’s lives in effective and meaningful ways. This is generally described as a problem of translation, of education or of struggling against political bias in the news media. However communicating climate science is more than just a problem of translating unpalatable facts through the filter of a biased news media to a generally disinterested audience. It is also a problem of how to translate what is a sprawling, multidisciplinary and computer mediated knowledge infrastructure spread across journals, digital models, labs and reports into a singular message that is meant to inform people’s practices, their politics and their interpretation of the world they live in. The difficulty that bedevils the communication of climate science is not just one of communication but a problem of how to engage people in the ecological relationality made evident through the distributed digital infrastructure of knowledge production.

To understand the problem here we need to understand something of the digital infrastructural qualities of climate science itself. Paul Edwards' magisterial book *A Vast Machine* provides a fascinating window onto this world. In the book, Edwards unravels the workings of the knowledge infrastructure of climate science, tracing both the history and sociology of climate modelling. Aware that demystifying the production of scientific knowledge on a topic like climate change runs the risk of its own misinterpretation, Edwards states from the outset that his analysis offers not a deconstruction on of the truths of climate science, but rather a description of the infrastructural conditions out of which climate science has been forged. In this Edwards follows in the footsteps of Bruno Latour and others working in the tradition of science and technology studies who use the method of tracing networks of relations to unravel the 'black boxes' of science and technology. In Edwards' case, the story that emerges from this meticulous tracing is not one that deconstructs the evidence of climate change but rather one that celebrates the amazing achievement of climate science as an assemblage that holds together findings, theories, technical devices, data traces and analytical techniques from disciplines ranging from earth sciences, atmospheric chemistry, computer science, geology, oceanography and policy sciences to weave a picture of a changing climate whose causes can be traced back to burning of fossil fuels for heating, industry and transportation and the practices of industrial agricultural production.

Whilst Paul Edwards' book helps us to understand the conditions out of which climate models have emerged and the nature of the knowledge that they produce, this stance does not however touch on the experience that non-experts have of engaging with these information infrastructures. The problem of how to communicate climate

science is unfortunately not resolved alone by a sociological analysis of how climate models are produced. Indeed as I heard one climate communicator point out in relation to the controversy over the Nature Geoscience paper mentioned above, 'all modelling is 'wrong' but this is a subtle point... The very fact climate science has to use modelling means it's always going to be under attack and called wrong each time you refine and revise it, for as long as there are editors who want to say it.'

The question then is not only how does climate science create evidence, but also how is the evidence that is produced in the manner adequate to climate science described and received in other arenas. How does one communicate as fact, something that is emergent, contingent, multidisciplinary, and in this climate scientist's own terms empirically 'wrong', without necessary going into a 400 page analysis of climate science itself? This demand generates its own responses and challenges which we will see as we turn our attention now to a science communication project launched in Manchester's Arndale centre in 2012 – the Manchester Carbon Literacy project.

Literacy and Social Learning

It was as part of the city of Manchester's attempts to tackle climate change, that community activist Phil Korbel and former IT consultant Dave Coleman came up with the idea of the Manchester Carbon Literacy project. The project was to be a way of responding to the question of how to bring about the cultural change that would be necessary to do something in the city about climate change. The project involved putting together an accessible public engagement and education tool that would be offered to every worker and citizen in the city of Manchester so as to improve their

understanding of the science of climate change and how it related to their lives. Supported by the city council and many organisations in the city, the carbon literacy project was launched in October 2012 by Richard Leese, Head of Manchester City Council, at a city centre shopping centre to an audience of 150 or so representatives of schools, businesses, universities and charities who had pledged their support for the programme.

The carbon literacy project was an example of many such attempts to engage people in the ecological relations made evident by the digital knowledge infrastructure of climate science, and make it relevant to people's lives. The carbon literacy programme set out to improve people's understanding of their involvement in climate change by explaining to them a) the science of climate projections b) the role that greenhouse gas emissions are playing in atmospheric change and c) how people's everyday activities contribute to global climate change. Whilst the project was set up as a literacy programme it was not simply didactic, but aimed to generate a form of public participation in the problem of climate change.

One part of the public engagement was an online learning tool. This web-based platform was designed to provide people with some of the basic science of climate change. Here summaries of information about global temperature change and levels of global carbon emissions were displayed – with links to the Met Office and other sites where people could check information for themselves and question and answer sections where people could test their understanding. Moreover the information provided on the site was repeatedly tied back to Manchester – as site of the industrial revolution, as a place where particular climatological effects were projected to

happen, and as a location which was contributing a specific amount to global climate change. But it was also very clear to those designing the carbon literacy programme that an online tool could never be enough.

To accompany the website a half day face to face workshop was also designed that would be attended by people who were signed up to the carbon literacy programme. In the face-to-face training session, the people attending were not instructed but were asked to think about their carbon footprint with the evidenced information that they had been provided with. The session I attended started with an 'icebreaker' exercise of 'green bingo'. The twelve council employees in the room were each given a 'bingo' card with a grid of boxes inside of which were listed a range of green behaviours – 'cycles to work', 'recycles', 'always turns off computer screen', 'is vegetarian'. People then had to go around the room asking others if they did one of the behaviours until all the boxes were ticked off.

Participants were then introduced to different ways of representing their own involvement in climate change. First two kinds of carbon footprinting were introduced. The first was a footprint that calculated an individual person's carbon footprint in terms of tonnes of CO2 emitted from their everyday activities. The project used an online tool[6] (oneplanetliving.org) that asked people a series of questions about travel, food eaten and type of houses that people lived in. The output of this carbon footprint was an individual figure in Tonnes of Carbon Dioxide Equivalent (TCO2) that each person could calculate for themselves. However problems with this form of measurement were discussed. The people running the workshop recognised

[6] Available through the website oneplanetliving.org (last accessed 10th May 2018)

that this calculation was itself not easy for people to grasp. Discussion ensued about how best to represent something like carbon dioxide, how to understand for example how much is a lot or a little carbon dioxide? One question was what does 5tonnes of CO2 *look like*? In another climate change workshop that was run as part of a different carbon reduction accreditation scheme, one of the organisers had tried to tackle this problem by bringing along a photograph that depicted the volume of a tonne of CO2 . The organiser of that workshop also used the analogy of 'so many double decker buses' to describe a volume of CO2e. In another conversation with a climate scientist he told me about an art/science project he had heard of where the artist had found a way of drawing people's attention to their carbon footprint at the airport, by telling people when they got off a flight how many bags on the carousel represented the volume of CO2 they had emitted as a result of the flight they had just taken.

The other way of representing people's environmental impact was not through carbon footprinting measured in tonnes of CO2e but through ecological footprinting measured in terms of the area of the planet that was needed to support each person's lifestyle. Scaled up to the global population, this allowed people to see 'how many planets we would need if everyone lived like you'. Most people in the room found that we were in need of two to three planets if everyone 'lived like them'.

All of these devices were ways of trying to make sense of the relationality of climate science revealed by digital infrastructures of measurement and modelling and to make it relevant for people[7]. From the outset of the project the organisers had decided not to

[7] There have been critiques of these kinds of carbon literacy schemes which see them as an extension of practices of neoliberal governmentality, asking the individual to

use the carbon literacy programme as a simple science communication tool but to see it as a way of engaging people in a more extended understanding of the problem of climate change. They used terms like 'social learning' to explain the intention of the project to 'embed behavioural change' in people's lives. This involved the use of teaching methods that focused on making the material taught 'directly relevant to where the learner is and 'modelled' for learners'. Another key principle was that the training would be delivered by peers as far as possible rather than outside experts. In this model people who had done the carbon literacy training themselves would then become potential future trainers under a 'train the trainer' logic which was meant to both personalise the abstract science of climate change, and allow the training to reach a big audience in a short amount of time[8]. Ecological relationality was not just the content of the lesson being taught, but also bled into the form through which that lesson was itself structured and delivered.

Conclusion

How to deal with the impossibility of ultimately knowing the unfolding digital infrastructures of everyday life raises issues not just for those who are grappling with these systems in their everyday work, but also for social scientists and anthropologists. Given the complexity of these systems and the unknown-ness of their implications which form and change at the same time as we try to understand them then how should we proceed? One answer is to try to find ways of describing the infrastructures 'themselves'. This cannot be a matter of going to the experts to ask

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take responsibility through the management of their own conduct (Stripple). Whilst this is a reasonable critique it is not my focus.

[8] These quotes are taken from a draft of the Manchester Carbon Literacy Standard which was being developed at the time of my research.

them how things work, for what we find with digital infrastructures is that our own questions about what infrastructures are and how they work are often shared with those with whom we are doing research. In the face of such infrastructures, it turns out we are all social researchers of sorts. At the same time, the way in which these infrastructural systems are pursued and sustained by fetishistic marketing that occludes the institutional and material structures that are actually being invoked does seem to demand a more critical attention that is able to trace their actual manifestations rather than just their dream-like promise. Describing the specificity of digital infrastructures as they are designed, tested and implemented offers a way of tracing the often unacknowledged social and political relations that become hidden by the vernacular dream-image of smart cities or blockchain enabled transparency. At the same time, we need to recognise that endlessly tracing networks of relations is a Sisyphean task which will never provide an ultimate picture of how things are. If we start with a belief in digital infrastructures as a network that can ultimately *be* traced, we risk blinding ourselves to what we can learn from the inherent *untraceability* of the relations that constitute the world of digital infrastructures. In the examples I provided of two digital infrastructures we discovered some creative responses to this opacity. *Infrastructural Inversion* and *Social learning* appeared as two kinds of sociality that emerged out of an attempt to consider what it means to live with and in relation to complex and distributed infrastructures. Similarly, for ethnographers of digital infrastructures, I suggest that allowing the conditions for opacity to be acknowledged rather than done away with must be key to how we approach them. In this chapter I have suggested that staying with the opacity and uncategorisable qualities of digital infrastructures and their relations, can reveal to anthropology that digital infrastructures have not only informational and network characteristics but also

with their ecological qualities. Rather than tracing networks, our job could instead be to attend to these ecologies – attending to how infrastructures become constituted relationally rather than becoming overly preoccupied with their ontological characteristics. With this perspective digital anthropologists would no longer only be the observers of digital infrastructural systems but could also become newly involved in shaping, critiqing and transformign them. For as Gregory Bateson reminds us: "in fact the problem of how to transmit our ecological reasoning to those whom we wish to influence in what seems to us to be an ecologically "good" direction is itself an ecological problem. We are not outside the ecology for which we plan – we are always and inevitably part of it' (Bateson 1972: 512).

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