The constitution of electricity demand in Central Manchester: practices, infrastructure and spaces

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I hereby declare that this thesis is my own work, and has not been submitted in substantially the same form for the award of a higher degree elsewhere. I confirm that the word length conforms to the permitted maximum.

Contents

List of Charts, Figures, Tables and Images

Charts

Figures

Tables

Images

Abstract

Energy demand has been conceptualised and studied as an outcome of the organisation and performance of social practices and of relationships between practices and infrastructures. Detail regarding the spatial features of these relationships remains underdeveloped. This thesis focuses on the shifting sites of electricity provision and demand, as these relate to changes in the mixture of residential and commercial activity in Central Manchester from 1984 to present.

The thesis consists of four linked studies, each designed to provide new insights into the spatial organisation of electricity provision and consumption. The first shows how patterns of electricity demand and land use change together within the centre of the city over time. The second shows that these developments relate to and reflect events and trends that extend beyond the city. The third study follows the construction of one critical part of Central Manchester's electricity infrastructure and the fourth shows this to be an outcome of relations that again extend well beyond the city itself.

These studies, based on expert interviews and secondary data, including maps, schematic diagrams and official plans and strategies, move between scales and between aspects of provision and consumption to provide a subtle and complex account of how practices and infrastructures shape each other across scale.

Together, these studies reveal changing relationships between practices and the electricity network at different geographical scales and provide new insight into the emergence and types of 'global-local' flows, thresholds, and critical moments that characterise the constitution and the dynamics of electricity demand over time.

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This thesis is dedicated to my partner, Lottie Butcher.

Figure 1: Central Manchester, reproduced from Plate 72 from the *City of Manchester Plan* (Manchester City Council, 1945, cited in Dodge and Perkins, 2009, p. 19)

Chapter one: Introduction

This thesis is about the constitution of electricity demand in Central Manchester between 1984 and present day (Figure 1). During this time, Central Manchester has changed from a largely industrial and commercial site, marked out by dereliction and land vacancy, to a residential and commercial hotspot (Peck and Ward, 2002; Haslam, 2004; Rae, 2013). This transition has involved a ‘boom’ in development, experienced broadly since the turn of the millennium, with Manchester emerging as one of the UK’s fastest-growing cities, both in terms of population and economy (Williams, 2003; Harding et al., 2010; Rae, 2013; Thomas et al., 2015; Elliott, 2018; Deloitte, 2018, 2019).

While scholars have tended to focus on the social, economic and cultural nuances and implications of Central Manchester’s changing form and function (Guy et al., 2002; Peck and Ward, 2002; Williams, 2003), this thesis concerns its ‘global-local’ (Massey, 1991, 2005) formation, land use change, and the related organisation of the electricity system. I focus on these themes in order to reveal the constitution of electricity demand in the centre of Manchester since 1984. As a consequence of conceptualising, studying and revealing the constitution of electricity demand in Central Manchester, I contribute to discussions concerning how electricity demand takes shape at different scales and to conversations about how and why electricity networks extend and change over time (Hughes, 1983; Bijker and Law, 1992; Verbong and Geels, 2007, 2010; Shove and Trentmann, 2019).

I specifically raise and address the following questions:

- How has Central Manchester’s land use change and development, between 1984 and present day, depended on and affected the organisation of the electricity system?

- What does studying the relationships between the organisation of the electricity system and Central Manchester's changing form and function reveal about the constitution of electricity demand?

- How do relationships between the changing form and function of the city and the organisation of the electricity system play out at different but also intersecting 'scales'?

These questions are addressed through four different case studies which involve the use of a mix of methods, including: expert interviews, mapping, and engagement with secondary sources, such as schematic diagrams, maps, datasets, and other relevant publications and literature. The development and use of four different case studies reflects an attempt to meet the challenge of 'seeing' the constitution of electricity demand in Central Manchester by focusing on the changing composition of practices in the city and asking how such change relates to the organisation of the electricity system.

As a consequence of this approach (i.e. working with four different case studies), four ways of 'seeing' and articulating the relationships between practices and the electricity system, and how such relationships are constituted and take shape at different scales, are provided. Because part of these articulations are about the constitution of relationships across different scales, this thesis shows how the constitution of electricity demand happens within and at the same time extends beyond Central Manchester. Indeed, this thesis shows how electricity demand in Central Manchester can be conceptualised and interpreted as part and parcel of multiple 'global-local' flows and intersections, which inform and shape the city's spatial development and the electricity system over time. As part of providing this 'global-local' account of the constitution of demand in Central Manchester, I also show how the hardware that comprises the electricity system is organised to enable and respond, at different scales, to the spatial ordering of bundles of electricity-demanding practices, thus reflecting and permitting the ongoing changing form and function of different sites.

Additionally, this thesis brings into question the notion of ‘the’ electricity system. It does so by showing how multiple discursive versions of the electricity system are enacted by various actors and organisations involved in managing and making the system at different spatial scales. Studying and discerning different views of ‘the’ system further allows me to describe and conceptualise the dynamics that inform the organisation of and investment in hardware that supplies electricity to Central Manchester. In combination, the insights generated in this thesis have implications for those interested in conceptualising and studying the scalar relationships between practices and the electricity infrastructure, and those, be they professionals or academics, concerned with the dynamic organisation of hardware that supplies electricity.

By way of introduction, I begin by explaining why I focus on the constitution of electricity demand in Central Manchester. I then introduce several key orientating ideas and concepts. The thesis outline is presented in the final section.

Electricity demand

Electricity use and generation have increasingly formed topics across a range of social science disciplines (Chappells, 2003; Franco and Sanstad, 2008; Breukers et al., 2013; Powells et al., 2014; Shove et al., 2015; Hui and Walker, 2017; Hui et al., 2018; Smits, 2019). Within a collection of such works, a concern for the dynamics of electricity demand has formed a central concern (Shove and Walker, 2014; Hui and Walker, 2017; Hui et al., 2018; Shove and Trentmann, 2019; Smits, 2019). Electricity demand is understood to be an outcome of the ordering and accomplishment of electricity-demanding social practices (Shove and Walker, 2014). This understanding acknowledges that much of everyday life around the world now depends on the entwined consumption and supply of electricity. Accordingly, scholars concerned with electricity demand have focused on what electricity is for and how specific needs are formed and provisioned for (Shove and Walker, 2014; Hui and Walker, 2017; Hui et al., 2018; Shove and Trentmann, 2019; Smits, 2019).

The interest in electricity demand reflects, in part, a broader growth in energy-oriented research and concern for issues of sustainability and the related challenges posed by climate change (Shove and Spurling, 2013). Set in this wider context, electricity demand is a particularly important topic as changing and managing patterns of electricity consumption are seen as a key means of meeting various climate change aims and objectives (Franco and Sanstad, 2008; Breukers et al., 2013; Goulden et al., 2014). Understanding how electricity demand is constituted over time and at different scales are therefore important topics, even though, as Shove and Trentmann (2019) note, relatively little work has gone into considering the multi-scalar constitution of demand. The following discussion elaborates on why studying the constitution of demand at different scales is a particularly important and relevant topic.

A growing dependence on electricity

Electricity is now generated and consumed on a global scale. The scale of generation and consumption is staggering given that the discovery of electricity is generally attributed to Benjamin Franklin's eighteenth-century kite experiment (Hughes, 1983). It is even more impressive given that the domestic supply of electricity only started taking shape in 1882, in Manhattan, and for purposes of lighting (Hughes, 1983). Over the course of the twentieth-century, however, electricity has come to form an essential, if not always conspicuous, component of everyday life. As Graham and Thrift (2007, p. 13) argue, quoting Leslie (1999), 'we are all hostages to electricity'. Indeed, for people living in cities around the world, electricity is now essential to all manner of activities, including cooking, cleaning, showering, commuting to and from work, and completing various working tasks (Pranab et al., 2019).

On a global scale, the dependence on electricity is also set to grow with aims to increase worldwide access to electricity and a growing reliance on various electricity-demanding appliances expected to continue (Panos et al. 2016; Sustainable Energy for All, 2018; Statista, 2019a). Following such aims and trends, in 2018, for example, the ‘Indian Prime Minister… announced that India [had] achieved its goal… of providing electricity to every village’ in the country (Murphy, 2018), while the amount of money spent on electrical appliances worldwide, between 2013 and 2018, rose by an estimated by 118.22 billion US dollars (Statista, 2019b). As a consequence of such changes, it is estimated that by 2050 ‘global electricity demand will reach around 38,700 terawatt-hours… [up] from 25,000 terawatt-hours in 2017’, marking a 57% increase in 33 years (Bloomberg, 2019). Between 2017 and 2018 alone, it is estimated that ‘global electricity demand… increased by 4%... growing nearly twice as fast as the overall demand for energy’ (International Energy Agency (IEA), 2019). This 4% growth culminated in 23,000 TWh worth of global consumption, ‘pushing electricity towards a 20% share in [the] total final consumption of energy’ (International Energy Agency, 2019). Electricity thus ‘continues to assert itself as the "fuel" of the future’ (IEA, 2019).

The growing global generation and consumption of electricity have clear environmental consequences. ‘In 2017, carbon dioxide [CO2] emissions from power stations… accounted for just under a fifth of all carbon dioxide emissions’ in the UK (Department for Business, Energy and Industrial Strategy (BEIS), 2018a, p. 10). And, on a global scale, the International Energy Agency (2019) estimates that in 2018 ‘emissions from power generation [accounted for] 38% of total energy-related CO2 emissions’. It follows that understanding the constitution of electricity demand and its management are increasingly important topics.

Electricity and tackling climate change in the ‘city’

Understanding the constitution of electricity demand is particularly important given, somewhat counterintuitively, increasing electricity generation and consumption are seen as a key means of achieving climate change targets (Transport and Environment, 2018; National Grid, 2018a; Keating, 2019). This is because tackling climate change and meeting decarbonisation targets currently depends on the increasing use of electricity to complete tasks previously fuelled by other means. In particular, the supported adoption of Electric Vehicles (EVs) and electric heating systems are key components of a carbon-neutral future, but only if electricity can be generated cleanly (Transport and Environment, 2018; National Grid, 2018a; Keating, 2019). Estimates by National Grid (NG), for example, suggest that 'the widespread use of electric cars in the UK and the end of gas boilers in homes will cause the country to reach its target of zero emissions of greenhouse gases' by 2050 (Cook, 2019). Such estimates hinge on related visions of the changing material organisation of the networked hardware that supplies electricity and increasing network capacity. In this regard, it is commonly acknowledged that the UK's electricity network must become 'smarter' and more receptive to growing demands and related attempts to meet decarbonisation targets by increasing the consumption of and reliance on electricity (Ceseña et al., 2016; Electricity North West, 2018a, 2018b, 2018c; Manchester Climate Change Agency (MCCA), 2016; National Grid, 2018a; European Network of Transmission System Operators for Electricity, 2018a).

The awareness that the networked hardware that supplies electricity must adapt to help achieve key climate change aims and objectives makes questions about the ownership, design and organisation of the electricity system particularly important. Equally significant are related discussions about which organisations and political authorities are responsible for reshaping the networked hardware that supplies electricity, and conversations concerning the scalar ordering of electricity infrastructure.

In regards the scalar organisation of electricity infrastructure, the 'city' has been foregrounded by different political actors and scholars (Betsill and Bulkeley, 2006; Rosenzweig, 2011; Bulkeley et al., 2014; Carter et al., 2015; C40, 2019; Core Cities UK, 2019). This foregrounding builds on the idea that cities appear to offer a particularly useful scale to tackle climate change and achieve related aims and objectives. Building on this premise, the C40 Cities Climate Leadership Group (C40) represents a 'network of megacities committed to addressing climate change' by taking responsibility for and reshaping the organisation of energy and thus electricity consumption and generation in specific urban locales (C40, 2019). Central to the C40 (2019) programme is a claim that 'cities are the key to addressing the global climate change problem', a declaration echoed by the Core Cities UK Group, which is comprised of Birmingham, Bristol, Cardiff, Glasgow, Leeds, Liverpool, Manchester, Newcastle, Nottingham and Sheffield (Core Cities UK, 2019). Together, the Core Cities UK group account 'for around 30% of England's carbon emissions' (Core Cities, 2019, p. 1). The group argues that as cities 'contribute to the causes of climate change… they can also provide solutions' (Core Cities, 2019, p. 1). This argument is reproduced, in reference to a global-scale, in the Organisation for Economic Co-operation and Development (OECD) *Competitive Cities and Climate Change* working paper, within which it is asserted that 'cities are part of the climate change problem, but they are also a key part of the solution' (Kamal-Chaoui and Robert, 2009, p. 3).

The now common tendency to suggest the challenges of climate change can be fruitfully addressed at the scale of the city begs questions about how electricity demand is constituted in the city. Whether city authorities, including MCC, are really in a position to mitigate and tackle climate change and the linked production and generation of electricity is also questionable.

Together, the points made in this section explain why electricity demand is an important topic and why studying the constitution of demand in cities is an especially salient issue. Having made these points, I explain why I chose to study the constitution of electricity demand in Central Manchester.

Electricity demand in Central Manchester

Since the 1980s, Central Manchester has experienced a period of significant land use change and regeneration (Peck and Ward, 2002; Williams, 2003; Haslam, 2004). Due to its marked development and change, Central Manchester is a particularly relevant site to study the constitution of electricity demand. This suggestion is premised on the idea that the use of land connects with the consumption and generation of electricity (Owens, 1986), and that studying Central Manchester's changing form and function provides an opportunity to consider the constitution of geographies of electricity supply and demand as these change over time. In this section, I describe, in brief, Manchester's development and change, while also providing empirical detail regarding electricity consumption in the city.

During his tour of the British Isles, between 1724 and 1727, the author Daniel Defoe (2019) wrote the following remarks about Manchester:

> From hence we came on to Manchester, one of the greatest, if not really the greatest meer village in England… it is neither a wall'd town, city, or corporation.

By 1931, however, Manchester was one of the largest cities in the UK, with an estimated population of 766,400 (Leary, 2008). As Leary (2008, p. 224) writes, Manchester witnessed 'spectacular growth… [becoming] the workshop of the world' between the eighteenth and early twentieth centuries. So pronounced was the city's growth and global prominence that it became known as 'Cottonopolis' (Leary, 2008, p. 224) – a pseudonym linked with the city's connection with the production and exchange of cotton.

Having reached the zenith of its industrial and commercial power in the early twentieth-century, Manchester subsequently experienced a prolonged period of decline, both in terms of its economy and population (Williams, 1996; Leary, 2008). As Chart 1 shows, between 1931 and 2001, the city experienced ongoing population decline, with the sharpest drop taking place between 1961 and 1971 (MCC, 2019). During the ten years between 1961 and 1971, the city's population is estimated to have fallen from 661,791 to 543,650 residents, representing close to an 18% drop (MCC, 2019).

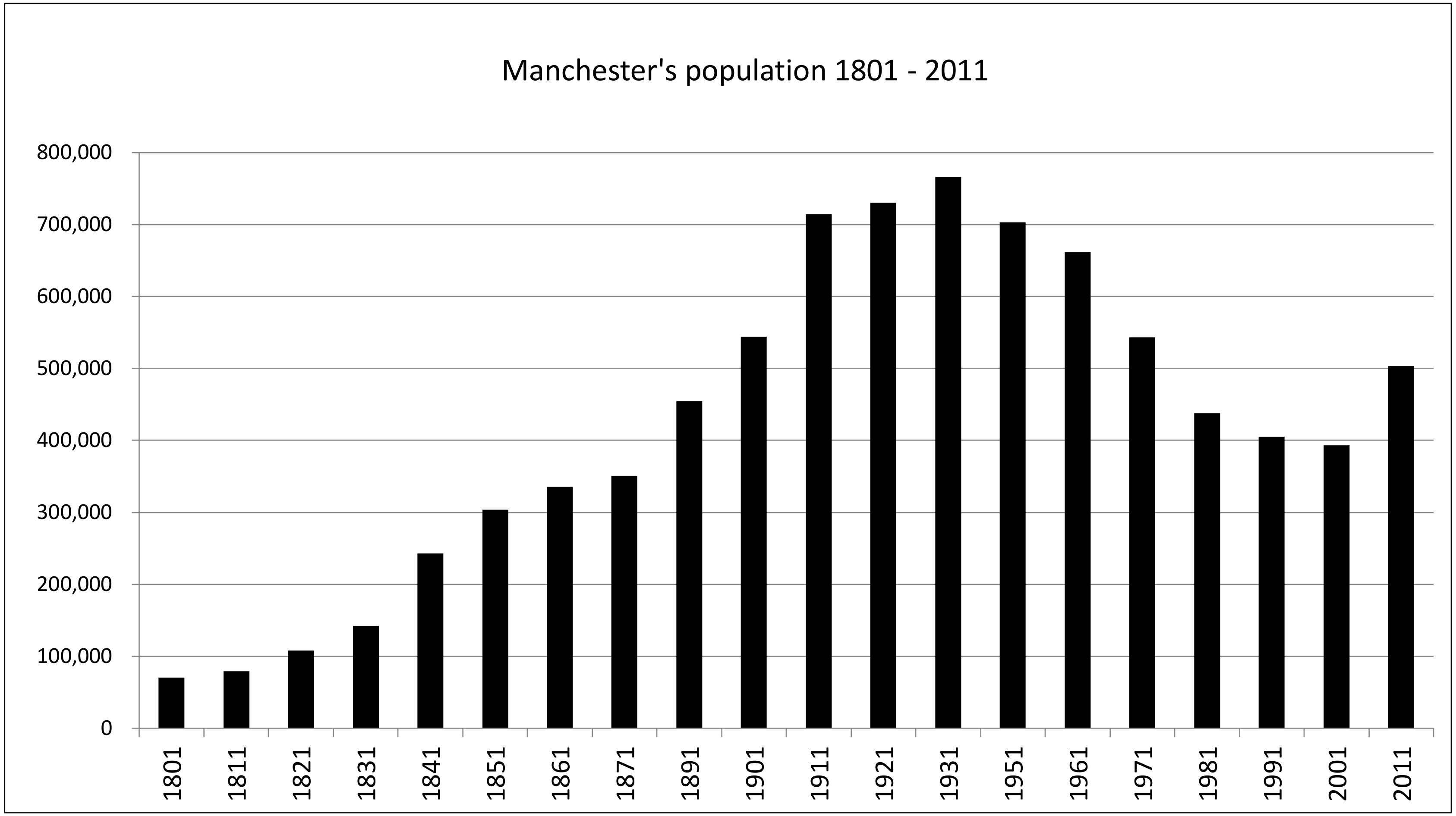

Chart 1: Manchester’s population between 1801 and 2011 (MCC, 2019)

In Central Manchester, it is estimated that there were a mere 250 to 300 residents living in the city centre in the late 1980s (Williams, 2003; Harris, 2015) - a place once home to thousands of industrial workers (Engels, 2009). It is further estimated that 'the number of jobs in the city centre dropped from 160,000 in 1961 to 99,000 in 1991' (Law, 2000, p. 117).

Following these trends of decline, much of the city centre was marked out by dereliction and land vacancy by the early 1980s (Haslam, 2004; Kidd, 2004). For Haslam (2004, p. 90) parts of the city centre, in the 1980s, offered 'the best example of urban dereliction you could find anywhere in the world'. He writes that 'there was an estimated 20 million square feet of empty industrial floor space in Manchester' in 1983 (Haslam, 2004, p. 90).

By stark contrast, Manchester is now one of Europe's fastest growing cities both in terms of population and economy (Rae, 2013; Harris, 2015; Deloitte, 2018, 2019). The city's contemporary resurgence is captured in the population growth experienced between 2001 and 2011, which marked the end of seventy-years of decline (see Chart 1 above). This growth saw the Manchester local authority region's population grow at a faster rate than any other town or city in the UK between 2001 and 2011 (Rae, 2013). This growth was further concentrated in the centre of the city (Harris, 2015; Thomas et al., 2015). Specifically, 'Manchester's city centre population almost tripled between 2001 and 2011 (Thomas et al., 2015, p. 17). The concentrated nature of population growth, between 2002 and 2016, is represented by Figure 2 and Figure 3 (Urbinfo, 2019).

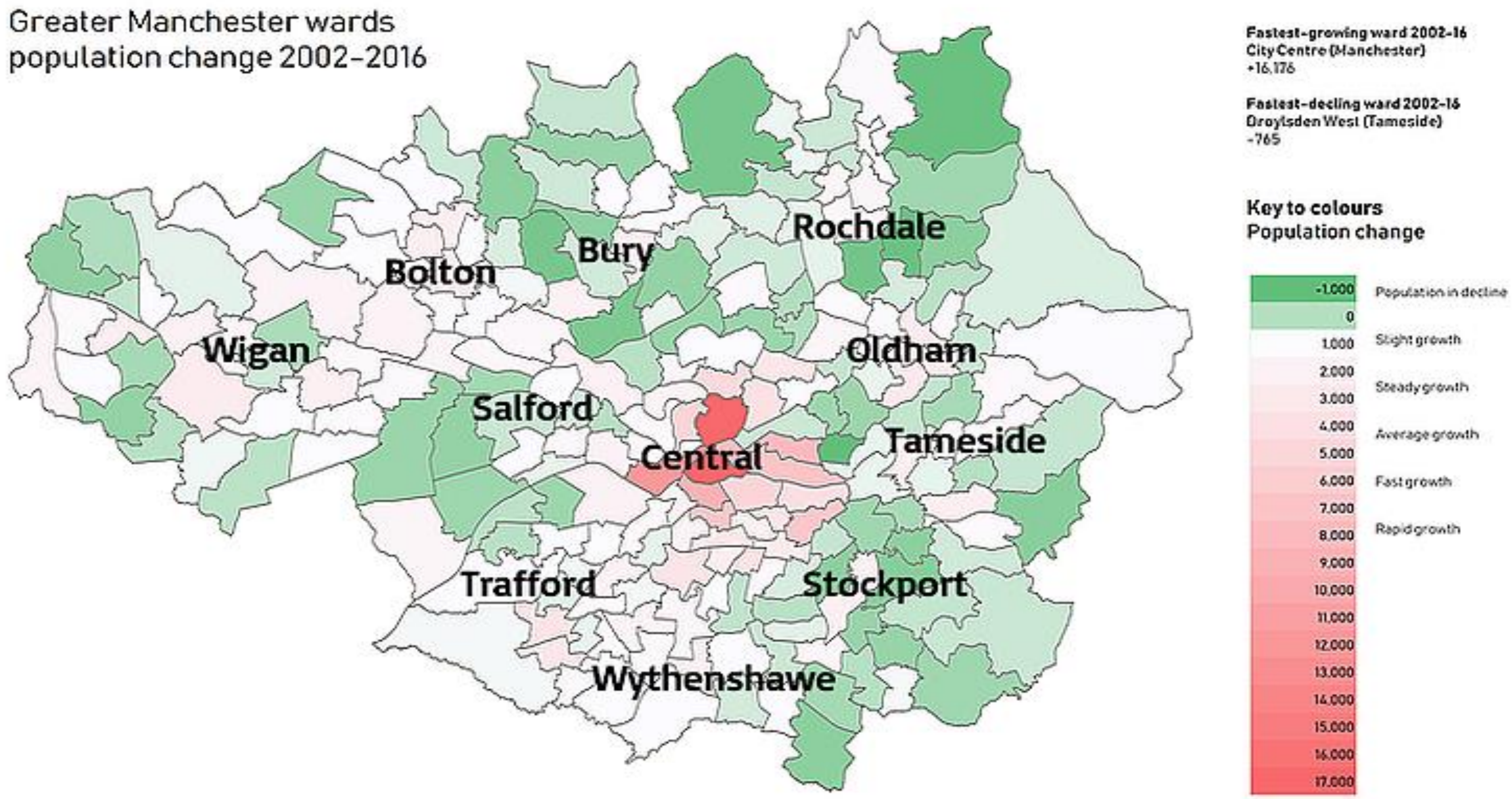

Figure 2: Greater Manchester Council ward population change between 2002 and 2016 (UrbInfo, 2019)

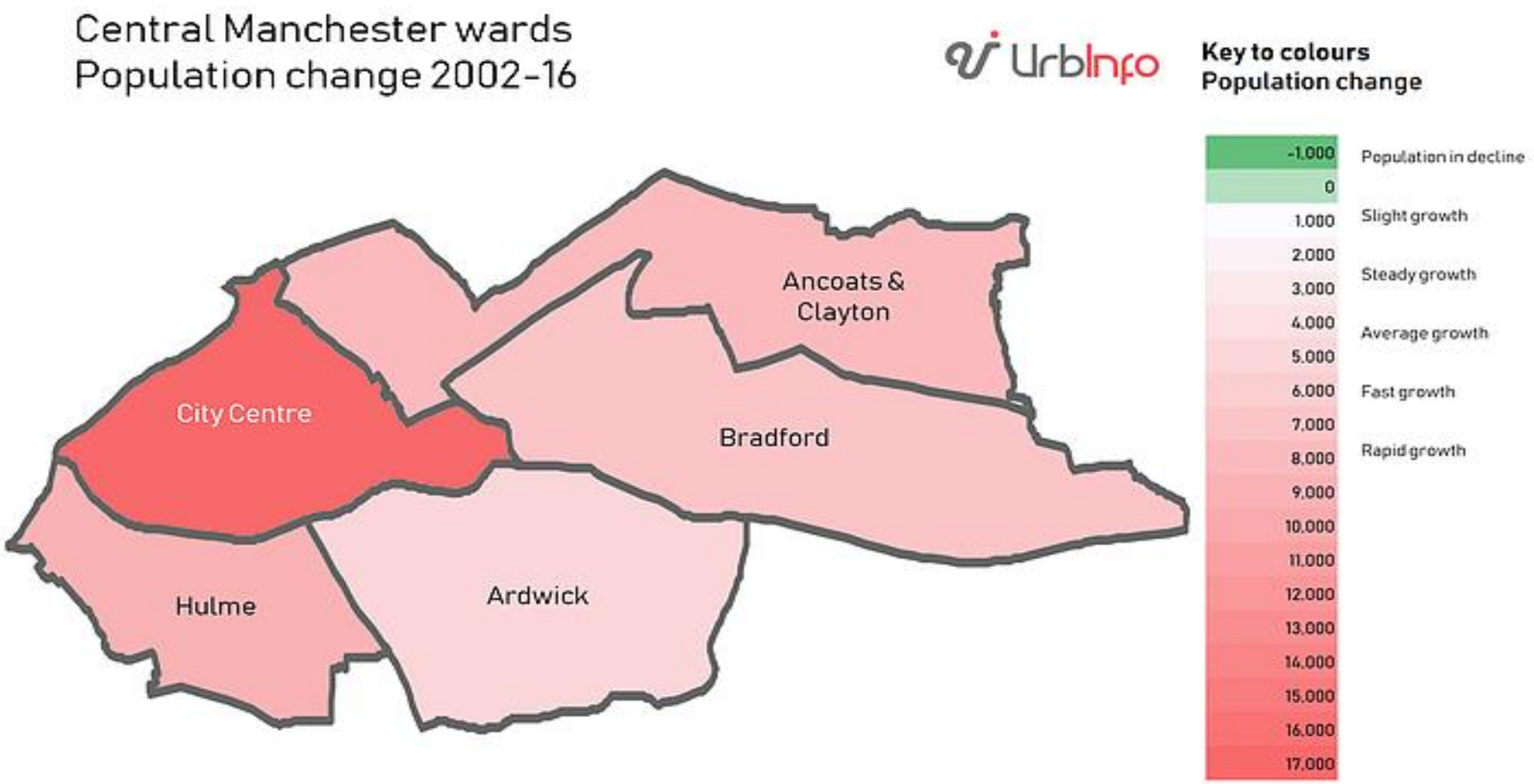

Figure 3: Council ward population change, between 2002 and 2016, in Central Manchester (UrbInfo, 2019)

The dramatic upturn in the number of people living in Central Manchester is mirrored by job growth in the city centre. Between 1998 and 2015, the number of jobs in the city centre grew by 84% (Thomas et al. 2015). This increase was the largest experienced in any city in England or Wales over the same period (Thomas et al. 2015). This centralisation is represented by Figure 4, which shows the distribution of jobs in the city centre in 2011.

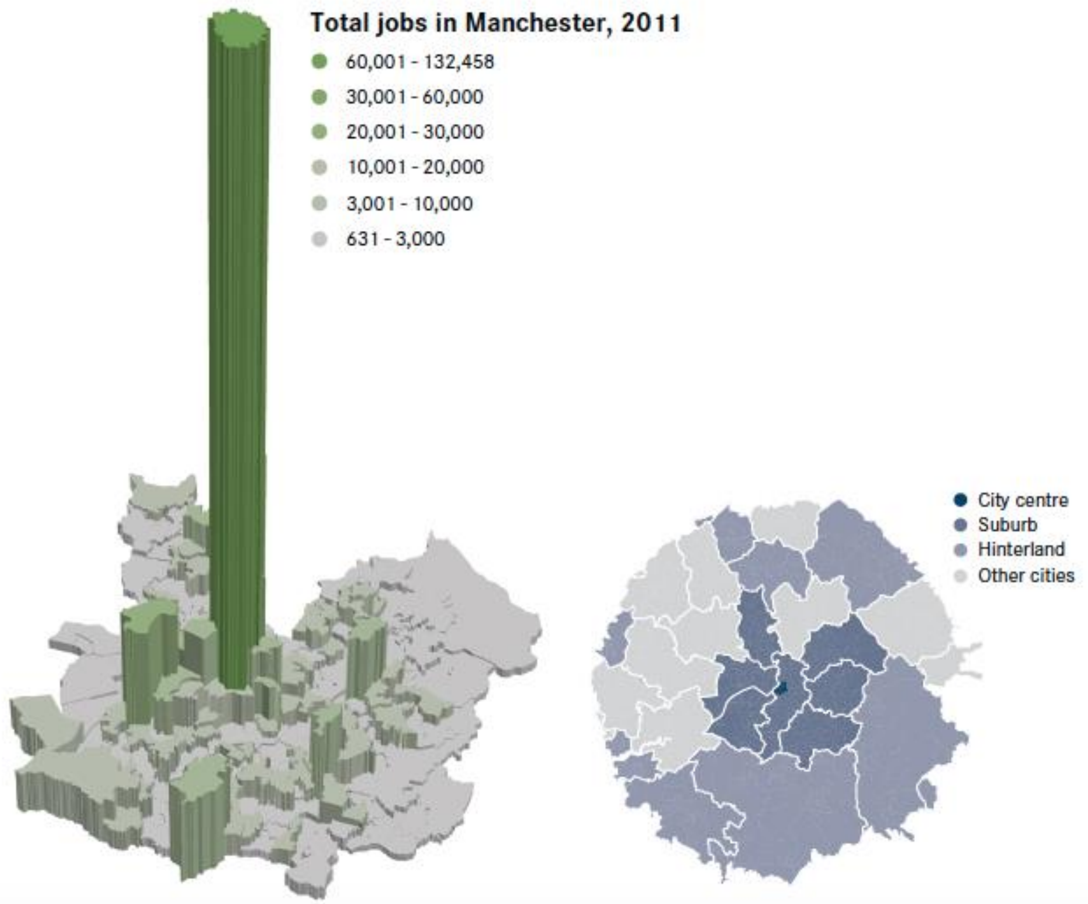

Figure 4: Geography of jobs in Central Manchester as of 2011 (Thomas et al. 2015, p. 17)

The city's broader and ongoing contemporary economic success is also reflected in the growing number of businesses locating in the city. Between 2014 and 2018, the number of businesses located in Manchester grew by 58% (Cachia and Greer, 2018).

As a consequence of such changes and the city's increasing population, Manchester is now seen as an archetypal example of how to do urban regeneration, with talk of the 'Manchester model' and the city representing the 'poster child' of redevelopment (D.K, 2013; Harris, 2015; Paxton, 2016; Begum, 2017; Hale and Bounds, 2019). The city's contemporary resurgence is such that it has become a case study site for scholars interested in the social, political, cultural and/or economic aspects and the effects of processes of urban regeneration (Williams, 1996, 2000, 2002, 2003, 2006; Batho et al., 1999; Deas et al., 1999, 2000; Quilley, 2000, 2002; Carlsen and Millan, 2002; Guy et al., 2002; Peck and Ward, 2002; Ward, 2003; Montgomery, 2005; Allen, 2007; Evans, 2007; Cook and Ward, 2011). However, Central Manchester's changing form and function also mean that it is a useful case study site to commence an investigation of the constitution of electricity demand over time and across different scales. This suggestion fits with the idea that electricity is not demanded for its own sake but as part of the accomplishment of everyday social practices in various sites, such as homes and workplaces (Shove et al., 2012; Shove and Walker, 2014; Hui and Walker, 2017; Hui et al., 2018). In turn, it makes sense to study the constitution of demand in Central Manchester – a site which has experienced a period of pronounced development.

The connections between the city centre's contemporary development and electricity consumption are captured in Lower Level Super Output Area (LLSOA[1]) data, which shows that average domestic electricity consumption in the centre of the city was higher than that experienced across the local authority region between 2012 and 2014 (Department of Energy and Climate Change (DECC), 2017; Department for Business, Energy and Industrial Strategy (BEIS), 2019a). Data concerning four LLSOAs in the centre of the city and covering the NQ (an

[1] 'LLSOAs are part of a geographical hierarchy… [which have] a minimum population of 1,000 equating to around 400 households' (DECC, 2011, p. 1).

area in Central Manchester studied in this thesis) specifically shows that average domestic electricity consumption was, between 2012 to 2014, over 64% higher than that experienced across the whole of the local authority region (DECC, 2017; BEIS, 2019a). This difference can, in part, be read as a consequence of the city centre's contemporary residentialisation seeing properties not connected to the gas network and thus dependent on electricity (Non-gas Map, 2018).

In contrast, non-domestic average electricity consumption per consumer and measured in kWh in two Middle Layer Super Output Areas (MSLOA[2]) in the city centre (again covering the NQ), between 2012 and 2014, shows a 70% differential with that experienced across the local authority region (DECC, 2017; BEIS, 2019a). However, in this instance, average non-domestic electricity consumption in two MLSOA's covering the NQ was on average 70% less than that consumed by industry and commercial consumers spread across the whole of the local authority region (DECC, 2017; BEIS, 2019a). This difference can again be interpreted in reference to trends in the city's contemporary development, with large-scale industrial sites no longer tending to be located in the centre of Manchester (Williams, 2003).

In terms of total electricity consumption across the Manchester local authority region, data concerning the ten years between 2007 and 2017 shows domestic electricity consumption decreased by 6.63%, from approximately 860 GWh to 803 GWh (BEIS, 2018b). Likewise, non-domestic electricity consumption dropped in the local authority region over the same period. Yet, only by 2.73% (BEIS, 2018b). These changes fit a broader trend of decreasing total non-domestic and domestic electricity consumption across the UK (BEIS, 2018c). However, decreases experienced at the scale of the UK have been sharper – a

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[2] MLSOA's are geospatial areas with an average population of 5,000 to 7,200 (DECC, 2011, p. 1).

point which suggests demand takes shape unevenly over time and across space (BEIS, 2018c). Between 2007 and 2017, total domestic electricity consumption across the UK fell by approximately 14.63% (BEIS, 2018c). Over the same period, non-domestic electricity consumption fell across the UK by 17.7% (BEIS, 2018c). Decreases, at a UK scale, have been explained as an outcome of technological change and increasing efficiency (Vaughan, 2018; BEIS, 2019b; Committee on Climate Change, 2019). Additionally, a broader shift away from industrial manufacturing has also been associated with decreasing total non-domestic electricity consumption across the UK (BEIS, 2019b; Evans, 2019; Vaughan, 2019).

The gross decreases in electricity consumption experienced across the UK and Manchester, between 2007 and 2017, are certainly beneficial in terms of the mitigation of climate change. Yet, the decreases discussed do not mean that electricity consumption and supply do not remain important topics. Particularly given that in the long-term electricity demand is expected to increase with the uptake of EVs and CHP (ENW, 2017a, 2017b; National Grid, 2019a), and that electricity consumption in the UK remains dependent on non-renewable sources of generation, with only 29.4% of the fuel mix made up renewables in 2017 (BEIS, 2018d, 2018e). Indeed, the forecasted growth in electricity consumption and continuing use of carbon-intensive fuels means that understanding the uneven constitution of electricity demand remains an important topic for researchers, policy makers and others interested in environmental issues and sustainability.

It remains, for example, important to ask questions that help explain why total domestic and non-domestic electricity consumption has fallen less sharply in Manchester, in comparison with the UK as a whole, between 2007 and 2017. Similarly, explaining why average domestic electricity consumption is higher in the centre of the city than it is across the local authority region is important for thinking about the effects of patterns of urban development and how they might be mitigated. Such details are of particular significance for political actors, including MCC, GMCA and the Manchester Climate Change Agency (MCCA), all of which are involved in addressing climate change at the urban scale (MCC, 2005; GMCA, 2016; MCCA 2016).

Continuing to work with the idea that electricity demand is a product of the ordering and sited performance of day-to-day activities (Shove and Walker, 2014), Central Manchester's contemporary development and the related uneven ordering of electricity-demanding practices render the area particularly useful to study of the constitution of demand over time. This exercise promises to provide insight into when it is and is not useful to conceptualise demand as a product of the 'city', and whether city authorities are best placed, as many of them claim, to tackle issues of climate change (C40, 2019; Core Cities, 2019). In approaching this topic and studying the constitution of electricity demand, I make use of several key intellectual resources and concepts, as introduced and discussed below.

Orientating concepts

The questions raised and addressed in this thesis reflect my engagement with specific ideas and concepts concerning energy demand, infrastructure and space. In this section, I explain how my study builds on an understanding that past, current and future demands are a product of the co-constitutive relationships in and between practices of consumption and those linked with energy provisioning and the ordering of infrastructures (Schatzki, 2011; Shove et al., 2015; Shove, 2016). Keeping this idea insight and taking it forward, in a way that represents specification of Massey's (2005) work, I suggest that the constitution of electricity demand involves a 'knotting' together of multiple and diverse practices and related policies, trends and events connected with consumption and supply, which have situated and yet also dispersed and thus scalar and spatial characteristics (Hui and Walker, 2017; Hui et al., 2018).

Demanding practices in Central Manchester

As explained, electricity and more broadly energy demand have been conceptualised, approached and studied as an outcome of the ordering and accomplishment of various social practices (Shove and Walker, 2014; Hui and Walker; 2017; Hui et al., 2018). Engaging with different definitions, particularly those articulated by Schatzki (1996) and Reckwitz (2002), Shove et al. (2012) define practices as made up of three elements: materials, meanings and competencies. Examples of social practices include those of Nordic walking, cooking, showering, doing the laundry, driving (Hand et al., 2005; Pantzar and Shove, 2010; Shove et al., 2012; Ryghaug and Toftaker, 2014; Warde, 2016; Mylan and Southerton, 2017). The idea that electricity demand is a product of the organisation and enactment of social practices depends on an understanding that practices, such as those referred to, depend on and affect the generation, supply and consumption of different sources of energy, including electricity (Shove and Walker, 2014). This is to acknowledge that electricity is not generated or consumed for its own sake but as a consequence of enabling and conducting various everyday social practices.

The ordering and performance of energy-demanding social practices have been shown to reflect temporal and spatial characteristics (Schatzki, 2011; Shove and Walker, 2014; Hui et al., 2018). This is because there is a spatio-temporal rhythm to everyday life, and this is seen in the ordered performance of social practices in different sites (Schatzki, 2011; Shove et al., 2012). It is also clear that the spatial and temporal ordering of practices has a history, which is to say that the timing and sited organisation and performance of energy-demanding practices can be studied and traced out over time and in a location, such as the home or workplace (Shove et al., 2012; Spurling, 2015; Cass, 2018).

Tracing the constitution of electricity demand at the scale of Manchester city centre is, however, admittedly a difficult proposition, with cities comprised of a heterogenous collection of electricity-demanding sites. This is not to say that the temporal and spatial ordering of electricity consumption and supply cannot be 'seen' at the scale of the city, but only that a number of conceptual and methodological steps need to be taken to do so. In this regard, Land Use Change Statistics (LUCS) and related categories offer some respite. Although losing sight of how energy use changes over time in 'smaller' sites, such as homes and workplaces, land use statistics provide a means of 'seeing' shifts in the residential and commercial composition of a city at large and the related uneven spatio-temporal reordering electricity consumption. Framed in these terms, how and why a city's land use changes over time accordingly become particularly pertinent questions concerning the constitution of electricity demand.

The idea that demand is a product of practices of consumption and supply, means that the temporal and spatial ordering and the accomplishment of social practices across the city (as a site made of multiple sites) also depends on and affects the activities of professionals involved in the supply of electricity (Hui and Walker, 2017). This is to say that electricity demand involves the ongoing organisation of the electricity system and connects with the enactment of everyday practices of maintenance, repair, design and investment (Hughes, 1983; Frost, 1993; Graham and Thrift, 2007). Due to the large-scale organisation of the electricity system, both in institutional and geographical terms, multiple practices, connected with various companies, particular professions, histories, skillsets, views, and obligations are entangled and involved in the everyday provisioning of power (Hughes, 1983, 1987; Ellis, 1996; Aibar and Bijker, 1997). Understanding the constitution of demand accordingly also involves studying practices of provision and the connections between such practices and those of consumption (Hui and Walker, 2017).

Read in light of the ideas introduced here, and especially the point that electricity consumption, supply, and thus demand are the outcomes of the spatio-temporal ordering and performance of social practices, Images 1 and 2, taken from the top of the now obsolete Bloom Street Power Station[3], which once formed a key part of Manchester city centre's electricity network (Frost, 1993), provide a snapshot of the ordering of evening electricity demand in the centre of the city. Together the images show a mix of office blocks, commercial buildings, high-rise car parking and residential buildings, all of which are supplied with electricity and all of which have different daily and seasonal profiles.

Image 1: Picture of Central Manchester at night-time (28dayslater, 2019)

[3] These pictures were taken in 2013 by an anonymous photographer and are published here with their permission.

Image 2: Picture of Central Manchester at night-time (28dayslater, 2019)

As in other cities, patterns of electricity demand change during the course of the day. It therefore makes sense to view Central Manchester as a site comprised of a heterogeneity of connected electricity-demanding practices linked with consumption and supply, which have spatial and temporal dynamics. This approach fits with Amin and Thrift's (2002) conceptualisation of cities as sites marked out by a vibrancy, multiplicity and heterogeneity of practices.

Working with this conceptualisation of the city and idea that electricity consumption and supply are connected with the performance of linked social practices, electricity demand in Central Manchester is understood throughout this thesis to be an outcome of a spatio-temporal 'knotting' of multiple practices. Here, knotting means more than the coming together of multiple practices. As I develop the concept, knotting refers to the uneven tying together of various policies, trends, events and patterns of investment, which inform the ordering of electricity consumption, supply and thus demand, in a site, such as Central Manchester, over time. As will be shown, the knotting of practices, be they typically connected with electricity consumption or supply, can be understood to take shape and develop in ways that help to configure future knots, wherein patterns of energy demand are prefigured.

Demanding ‘bundles’ and ‘complexes’ of practice in Central Manchester

Thus far, I have acknowledged that while heterogenous and multiple, practices are connected in various ways, including across space and time (Schatzki, 2002; 2010a, 2010b; Shove et al., 2012). Additionally, such connections are understood to have implications for the constitution of electricity demand (Schatzki, 2011; Shove et al., 2012; Blue and Spurling, 2017; Blue, 2018). To help articulate the idea that the formulation of electricity demand relates to connections in and between practices, be they linked with energy consumption or supply, authors have developed a number of concepts concerning how practices connect as spatial and temporal formations.

Shove et al. (2012), for example, discuss bundles and complexes of practice. As they explain:

> Just as elements are linked together to form recognizable practices, so practices link, one to another, to form bundles and complexes. Bundles are loose-knit patterns based on the colocation and co-existence of practices. Complexes represent stickier and more integrated combinations, some so dense that they constitute new entities in their own right. (Shove et al., 2012, p. 62)

Cooking, eating and watching TV provides a simple example of a practice bundle, with different, yet also co-located and coexisting practices forming a loose-knit package, which tends to take shape in, whilst also shaping, the spatial organisation of the home.

As also captured in the quotation above, a complex is instead made of strong interdependencies between multiple practices, which are so dependent on each other that they are hard to distinguish and describe as separate entities. Shove and Walker (2014, p. 50) provide a useful example of a practice complex:

> Petrol-based systems of automobility require the continual, relatively faithful reproduction of an entire complex of variously interdependent practices, ranging from oil exploration through to garage forecourt operation, traffic management and driving itself. If these practices did not 'hang together' in the way they do today, the oil system that is thereby constituted and sustained would, of necessity, take some other form.

Working with these concepts, the dynamics of electricity demand - at different spatial scales, and over days, nights and decades - can be fruitfully interpreted as a consequence of the formation of bundles and/or complexes of practice.

It is possible, for example, to interpret electricity demand in relation to the organisation and texture of practice complexes, such as the petrol-based system of automobility. The dynamics of electricity demand related to this complex are vast and can be described in different ways. The demand for and the related production of goods, including tyres, oil, fuel and other resources necessary to drive, all hinge on the generation and use of electricity. The electricity demanded to make such essential materials contribute to the production of $C0_2$ attributed to road transportation, which, in 2008, accounted for an estimated 16.5% of total global CO_2 emissions (World Health Organisation, 2011).

Likewise, it is possible to consider changing patterns of energy demand as outcomes of the organisation of practice bundles. For instance, the evening surge in electricity use and generation experienced across the UK, generally between four and eight pm in the working week, can be linked with the formulation of a domestic practice bundle, including practices of cooking, showering, eating, watching TV and/or using the internet (Shove et al., 2009; Powells et al., 2014).

In terms of my own research and this thesis, these ideas imply that rather than concentrating on specific electricity-demanding practices, studying the constitution of electricity demand in Central Manchester involves following the composition of practice bundles and/or complexes in the city over time. This is to say that the composition of the city's electricity-demanding geography can be usefully conceptualised as a result of multiple and various bundles and complexes of practice, which, I suggest, further reflects an ongoing knotting of practices in the city, while not necessarily being made in the city itself.

Practices and the electricity system in and beyond Central Manchester

It is widely recognised that practice bundles and complexes depend on and shape infrastructures, including the electricity system, and such relationships have situated and distributed characteristics (Shove et al., 2015; Shove, 2016; Hui and Walker, 2017). Studying the constitution of electricity demand in Central Manchester thus requires focusing on the ordering of practices in the city, but also on how such formations depend on and relate to processes beyond the city, including the organisation of the UK electricity system.

The idea that studying the constitution of electricity demand in Central Manchester involves focusing on the co-constitutive, situated and also distributed relationships between practices and the electricity system, builds on the point that seemingly local actions are likely to be informed by and be part of more dispersed trends and relationships (Shove 2016; Hui and Walker, 2017; Rinkinen et al., 2017; Shove and Trentmann, 2019; Spurling, 2019). Spurling (2019) argues, for example, that the growth of driving and car ownership in Stevenage informed and depended on town planners' practices and related responses to here-and-now demands as well as to longer-term visions of the town. As Spurling (2019) shows, increasing car use took shape as a consequence of situated and co-constitutive relationships between practices of driving and those involved in town planning and the provisioning of road infrastructure and parking.

Shove (2016) considers similar themes in a chapter that moves between the discussion of just one section of a road (the A3) and the relationships between origins, destinations and modes of travel. As with Spurling (2019), a key implication of Shove's (2016) account is that the practice of driving and the development of infrastructure evolve in relation to each other, and that events in just one spot (a bend in a road) are linked to much more distributed changes in mobility. Additionally, Shove (2016) shows how the circulation of goods and people, in and between two central hubs of practice, London and Portsmouth, depend on and demand the constitution of an enabling and responsive infrastructure. Thus, the A3's development can not only be taken to reflect the demands associated with the changing practice of driving but also the changing form and function of two geographically detached cities, which differ in terms of size, heterogeneity and diversity, but are nonetheless linked and require linking via fast connecting roads.

Developing similar ideas, Hui and Walker (2017, p. 5) make the following suggestion:

> Understanding the energy demanded in the course of doing practices… depends… upon a consideration of the settings in which they are undertaken, and the practices that provision and maintain infrastructural arrangements and operational processes in these settings.

In their analysis, a residential apartment forms, for example, a 'setting'. Key for Hui and Walker (2017) is the idea that electricity demand is configured in relation to the form and function of 'doing-places' and 'settings', and in the situated and extended connections between such sites, which include those swept up in the production and delivery of electricity. Spurling (2019), Shove (2016), and Hui and Walker (2017) thus draw attention to the idea that the constitution of electricity demand in a location, such as Central Manchester, depends on other scattered 'doing places' and 'settings', including those connected with making sure that electricity is generated, transmitted and distributed to various and particularly demanding sites, such as the city.

The key empirical implication here is that interpreting the constitution of electricity demand in Manchester city centre involves analysing the changing form and function of Central Manchester and considering how this has depended on and affected the organisation of the electricity system in and beyond the city and thus across different scales. Building on the idea that constitution of electricity demand is an outcome of the co-constitutive relationships in and between various practices of consumption and supply, this task involves studying sited and distributed connections between practices linked with the city's change, including town planning and policy, and those implicated in the ongoing and longer-term maintenance and management of the electricity system.

Conceptualising the changing form and function of Central Manchester

Thus far, I have explained that Central Manchester can be conceptualised as a composite of practices and bundles of linked and interdependent practices, which have different spatial and temporal characteristics. I have also suggested that these practices and bundles are of consequence for the geography of electricity demand in the city centre. Building on this suggestion, I propose that the constitution of electricity demand in Central Manchester connects with the ordering of practice bundles in the city and the changing form and function of land, and further that both processes are expressions of trends that extend beyond the city itself. One way of thinking about such connections is to consider what Massey (1991, 2005) refers to as 'global-local' flows and intersections between multiple material practices.

Massey (2005, p. 9) conceptualises space as an ongoing production of a multiplicity of 'global-local' trajectories and intersections between material-practices. In detail, she argues that space should be read as a product of 'interrelations… from the immensity of the global to the intimately tiny' (Massey, 2005, p. 9). As the product of interrelations, space should also be recognised as 'the sphere of possibility… multiplicity… [and] heterogeneity' (Massey, 2005, p. 9). And, as the sphere of possibility, space should be interpreted as an ongoing formation, which is 'always under construction… [and] always in the process of being made' (Massey, 2005, p. 9).

Working with this conceptualisation of space suggests that the changing form and function of the city and thus the ordering of electricity-demanding practices are the product of 'global-local' flows and intersections, which take place in very material terms and in sited ways. From this point of view, understanding the constitution of electricity demand in Central Manchester is a matter of tracing 'global-local' flows and intersections, and 'seeing' how they knot together in and inform the city's changing form and function over time. This proposition follows Massey's (1991, p. 28) argument that places are 'articulated moments in networks of social relations'. As Massey (1991, p. 28) explains:

> … what gives a place its specificity is not some long-internalised history but the fact that it is constructed out of a particular constellation of social relations, meetings and weavings together at a particular locus.

Getting at the constitution of demand in Central Manchester thus depends on identifying, specifying and studying the relations and intersections that have met in and continue to re-make Central Manchester as a site in which practices settle and electricity demands take shape. This understanding complements the idea that electricity demand is constituted and made through extended and different forms of 'global-local' relationships and sited intersections in and between practices, linked with forms consumption and the organisation of infrastructures of provision (Hui and Walker, 2017; Rinkinen et al., 2017).

Throughout this thesis, I work with Massey's (1991, 2005) 'global-local' conceptualisation of space as a primary means of interpreting and making sense of the development of Central Manchester, the electricity system, and the constitution of electricity demand. In developing this approach, I suggest that the constitution of electricity demand in Central Manchester is also usefully conceptualised as a manifestation linked with how multiple 'global-local' flows and intersections combine and knot together over time, informing the changing and sited composition of practices in the city and the related organisation of the electricity system in and beyond Central Manchester.

Conceptualising the electricity system

Throughout this thesis, the electricity system that supplies Central Manchester is conceptualised as a socio-material formation. This is to say that the electricity system is understood as a geographically extended material arrangement which is managed and maintained by multiple organisations, comprised of various practices, and with different aims, objectives and related commitments (Hughes, 1983, 1987; Bijker and Law, 1992; Summerton, 1992; Summerton and Coutard, 1994; Star, 1999). Working with this conceptualisation means that understanding the constitution of electricity demand in Central Manchester also involves focusing on the socio-material organisation of the electricity system and exploring how this connects with the city's development over time.

This strategy is inspired by Hughes' (1987, p. 51) definition of technological systems:

> Technological systems contain messy, complex, problem-solving components. They are both socially constructed and society shaping. Among the components in technological systems are physical artefacts, such as the turbogenerators, transformers, and transmission lines in electric light and power systems. Technological systems also include organisations, such as manufacturing firms, utility companies, and investment banks, and they incorporate components usually labelled scientific, such as books, articles, and university teaching and research programme. Legislative artefacts, such as regulatory laws, can also be part of technological systems.

As this quotation demonstrates, for Hughes (1983, 1987), as for others writing in this tradition, technological systems are both social and material arrangements (Winner, 1980; Latour, 1988, 1996; Summerton, 1992; Star and Ruhleder, 1994; Summerton and Coutard, 1994; Star, 1999). This socio-materiality is further understood to shape and inform the ways in which physically extended, embedded and expensive systems, marked out by their obduracy and stability, change over time (Hughes, 1983, 1987; Star, 1999; Hommels, 2005).

At its simplest, writing in the tradition of work concerning the study of large technical systems (LTS) acknowledges that the demands, expectations and norms of a society are reflected in and shaped by the socio-material organisation of infrastructures (Hughes, 1983; Graham and Marvin, 1995). For energy systems, this means that the ordering of the hardware that comprises a technological system is an outcome of specific ideas and expectations concerning previous and future levels of demand (Shove and Trentmann, 2019; Spurling, 2019). In design and in use, wires, cables, plugs and substations, of varying capacities, are further symptomatic of intersections between practices of consumption and of provision – including the characteristics of the electricity system (Hughes, 1983).

Practices of consumption and supply, and intersections between the two, have been studied as a means of showing how past endeavours and future-oriented expectations led to and were supported by the detailed construction of specific infrastructures and capacities (Moss, 2008; Walther, 2016). Not all expectations are sustained in the long run. Moss (2008) and Walther (2016) show, for example, how previously thriving but now ‘shrinking’ cities may end up with systems that are oversized and too expensive to maintain. Such examples indicate a shifting geography of demand and highlight the connections between the changing form and function of sites and the material systems that underpin them. They also point to the value of studying the material organisation of the electricity system and asking, as in the case of this thesis, how a system’s development and change over time, at various scales, relates to and supports the ways in which Central Manchester develops.

Hughes (1983, 1987), Summerton and Coutard (1994), Star and Ruhleder (1994), and Star (1999) also draw attention to the ongoing day-to-day work that goes into managing and organising socio-technical systems and making them stable. This work is done by multiple actors and organisations who contribute to and help shape infrastructures (Summerton and Coutard, 1994; Star, 1999). This includes day-to-day forms of maintenance and ongoing repair (Star and Ruhleder, 1994; Star, 1999; Graham and Thrift, 2007; Bowker et al., 2010). Recognising that technological systems are socially shaped and shaping arrangements renders them inherently ‘lively’ constructs, which have to be and are always in the making as outcomes of the performance of various and intersecting practices (Graham and Marvin, 2001; Amin, 2014).

Together, these ways of thinking about infrastructure challenge the common tendency to simply ‘envision infrastructure as a system of substrates – railroad lines, pipes and plumbing, electrical power plants, and wires’, which form inert and backgrounded arrangements (Star, 1999, p. 380). Instead, when framed as works in progress and as products of the longer-term plans and strategies of multiple actors and organisations which operate in relation to particular assets, rules, aims and objectives, infrastructure becomes a 'fundamentally relational concept, becoming real infrastructure in relation to organized practices' (Star, 1999, p. 380). Understanding the constitution of electricity demand in Central Manchester consequently depends on studying how the electricity system is organised and maintained by various actors and the practices they conduct. This necessarily involves foregrounding and focusing on the system's organisation and asking how this connects with the 'global-local' flows and intersections understood to shape and inform the city (Massey, 1991, 2005).

Thesis outline

The thesis is structured as follows. In Chapter two, I introduce the research design and explain how I mobilise and work with the ideas and orientating concepts discussed in this chapter. I also explain my empirical starting points, including why I start in Manchester's Northern Quarter (NQ) and how and why I study the socio-technical organisation of the electricity system. Additionally, I set out and clarify how and why I work with four independent and yet complementary studies to explore the constitution of electricity demand in Central Manchester since 1984. The four studies comprise the different empirical chapters of this thesis.

In Chapter three, I focus on an area of the city centre, the NQ, as I provide a view of how the composition of electricity-demanding practices have changed there between 1984 and 2014. This is achieved by using Land Use Change Statistics (LUCS) (ONS, 2017a, 2017b, 2017c) and associated land use categories as proxies for practice bundles. In Chapter three, I identify an uneven trajectory of land use change marked by periods of relative stability as well as by moments of rapid development in particular directions.

'Zooming out' (Nicolini, 2009) of the NQ and taking inspiration from Massey's (1991, 2005) 'global-local' conceptualisation of space, in Chapter four, I use secondary data and interviews with planning experts to develop an account of the spatial ordering of electricity-demanding practices in the NQ and more broadly across Central Manchester between 1984 and present day. By working with this material, I make a series of connections between several ‘global-local’ flows, events and intersections which appear to have informed land use changes in the NQ and Central Manchester. By emphasising the ‘global-local’ dynamics that can be linked with the spatial ordering of electricity-demanding practices in Central Manchester, between 1984 and present day, I problematise the tendency to frame issues relating to energy and infrastructure as principally urban phenomena (Guy et al., 1997, 2001, 2010; Graham and Marvin, 1995, 2001; Moss, 2008; Monstadt, 2009; Graham and McFarlane, 2015; Moss and Francesch-Huidobro, 2015; Neill, 2016).

In Chapter five, I draw on interviews with Electricity North West (ENW)[4] employees and a range of secondary sources to describe and explain a specific instance of large-scale infrastructural change, namely the construction of the Central Manchester Primary 33 kV substation in 2009. I work with ‘technological frames’ as a key concept to help explain this investment and how it relates to the land use trends described in chapters three and four (Orlikowski and Gash 1994; Bijker, 1995; Aibar and Bijker, 1997). I show how shorter and longer-term developments in the spatial ordering of electricity-demanding practices depend on, whilst also challenging, the established stability and obduracy of the distribution network (Hommels, 2005). Building on this point, I suggest that the development and extension of the network that supplies electricity to Central Manchester is part and parcel of the work that goes into responding to and anticipating changes in what goes on within the city and the circulation and anchoring of practices within and between different sites.

I take a step back in Chapter six and consider the ways in which Manchester city centre and the Central Manchester Primary are connected to a geographically

[4] ENW is the Distribution Network Operator (DNO) that distributes electricity to Central Manchester and a wider geographical region.

extended material infrastructure, which is simultaneously managed by multiple organisations. Based on a review of twenty-eight plans, strategies and reports concerning energy and/or the electricity system, produced by either Manchester City Council (MCC), the Association of Greater Manchester Authorities (AGMA), the Greater Manchester Combined Authority (GMCA), Electricity North West (ENW), National Grid (NG), National Grid Electricity Transmission (NGET) or the European Network of Transmission System Operators for Electricity (ENTSO-E), I discern and introduce three different 'professional worldviews' of the electricity system (Ellis, 1996). These views are understood to be enacted and real in their effects. This is to say each view links with the production of a version of the electricity system. Each view and version of the system I articulate, conveys a different perspective on how and why the networked hardware that supplies electricity changes over time and how such changes relate to the constitution of demand in Central Manchester. By articulating and drawing attention to the production of different views of 'the' system, I suggest that 'the' electricity network is usefully conceptualised as a product of the enactment of particular organisational techniques, aims and objectives, which do not always mesh neatly with each other, and denote different scalar characteristics. In taking this approach, I question those who claim that networks are either largely urban assemblages (Tarr and Dupuy, 1988; Graham and Marvin, 2001; Monstadt, 2009) or that they are the outcome of the cultural, political and economic structuring of national settings (Correljé and Verbong, 2004; Verbong and Geels, 2007; Geels et al., 2016). Indeed, in contrast to Chapter five, where the focus is a single instance of large-scale investment in hardware, in Chapter six, I show how the network is made in response to and enables demands configured at different scales. My more subtle point is that these scales arise as a consequence of the mode of analysis and the professional worldview of the network and that these differ depending on the organisation involved.

Within the concluding chapter, I work through the main implications of this thesis and identify the contributions I make. Firstly, this thesis reveals different means of 'seeing' and articulating the relationships between practices and the electricity system as they take shape at different scales. Secondly, this thesis provides insight into the emergence of 'global-local' flows, which intersect and combine, sometimes culminating in critical moments that depend on and demand forms of network extension. In developing this approach, I provide a 'global-local' account of the constitution of electricity demand in and beyond Central Manchester, seeing it as an outcome of intersections between multiple flows which are part of shaping activity in the city and the electricity system. I further foreground the materiality of such intersections and how they occur over time and at different scales, arguing that the hardware of the network has both an enabling and responsive role. Bringing these points together, this thesis offers an account of the coexisting ebb and flow of change and stability within, across and between infrastructure and bundles of practice at different scales.

Chapter two: Research design

Introduction

In this chapter, I describe the design of this research project and how I address the central aims and questions identified in Chapter one. The research design builds on an understanding that 'the production of knowledge is a social practice' and that the methods used to study a phenomenon play a role in constituting the phenomenon studied (Sayer, 2010, p. 4). Building on this epistemological foundation, I consider the theoretical threads and related methodological moves that underpin this study of the relationships between practices and the electricity system, and how such relationships take shape over time and at different scales. This involves considering how I work with, extend and build on a collection of ideas and concepts linked with practice theory and Science and Technology Studies (STS) concerning practices, infrastructures and energy demand. I subsequently introduce the four empirical studies constructed and used to study the constitution of electricity demand. Focusing on each of the four lines of enquiry independently, I explain their design and how they provide a different set of insights regarding the constitution of electricity demand at different scales. Although the studies function independently, they also hang together in specific combinations. I detail these combinations in the final section of this chapter. Each combination reflects the broader logic of the thesis and a commitment to working through and describing how electricity demand takes shape and is handled.

Key ideas and new topics

In Chapter one, I set the scene by introducing some of the ways energy and electricity demand have been conceptualised, framed and studied. In particular, I explained how energy demand has been conceptualised and empirically approached, by those inspired by practice theory, as a phenomenon that takes shape as a consequence of the relationships in and between practices and infrastructures, including the electricity system (Schatzki, 2011; Shove and Walker, 2014; Hui and Walker, 2017; Hui et al., 2018).

Taking practices and infrastructure as central themes, alongside electricity demand as a broader topic, I work with and build on several ideas generated within practice theory and STS. It is at the intersections in and between works influenced by practice theory and STS concerning practices, infrastructure and energy demand, that the questions addressed in this thesis lie. Here, I revisit some of the orientating ideas introduced in Chapter one, while also introducing others, in order to explain the positioning and academic lineage of this thesis, the questions addressed and the novel contributions provided.

Practices, scale and demand

An ever-growing body of work concerning energy demand has been influenced by practice theory and the related 'practice turn' in social theory (Shove and Walker, 2014; Hui et al., 2017; Hui et al., 2018). The practice turn builds on and takes seriously Giddens' (1984, p. 2) suggestion that 'the basic domain of study [in] the social sciences… [are] social practices'. Within practice theory inspired works, energy demand is understood to be a social phenomenon related to the organisation and performance of social practices, examples of which, offered by Shove and Walker (2014, p. 47), include 'cooking, commuting to work, watching TV [and] conducting meetings'.

The interest in practices and demand has led scholars to conceptualise and consider, inter alia: what energy is for (Shove and Walker, 2014); how the timing of demand relates to the temporal ordering of practices (Anderson, 2016; Blue, 2017, 2018; Mylan and Southerton, 2017; Torriti, 2017); how energy demand changes over time and in relation to the demands of practices (Shove et al., 2015; Shove, 2016); how different forms of provisioning and infrastructure are implicated in, shaped by, and further affect the performance of everyday practices (Rinkinen, 2019; Smits, 2019; Spurling, 2019); how energy demand is configured as a spatial phenomenon (Hui and Walker, 2017; Cass et al., 2018); and, the connections in and between particular practices and/or the 'connective tissue' in and between specific practices and infrastructures (Hand et al., 2005; Shove et al., 2015; Shove, 2016; Blue and Spurling, 2017). The 'practice turn' in social theory has accordingly informed and shaped a body of research about the social, temporal, material and spatial dynamics of energy demand.

The contributions referred to open up a series of new questions regarding how demand takes shape over time and at different scales. While a selection of practice theory inspired works have taken up space as a central theme and focused on conceptualising and studying the spatial constitution of demand (Hui and Walker, 2017; Hui et al., 2018), there remains scope to study and focus more directly on the constitution of energy demand across space and at different scales (Shove and Trentmann, 2019). How, for example, the spatial anchoring of energy-demanding practices takes shape over time in a locale, and how such changes depend on and affect the material organisation and management of a specific energy infrastructure, at different scales, remain fresh puzzles. These puzzles concern the spatial ordering and distribution of practices and the related socio-material organisation of infrastructures.

Setting out to explore the spatial constitution of demand further poses a methodological challenge regarding how to approach and study the relationships between practices and infrastructure at different spatial scales. A novel approach, which draws on and extends ideas generated within practice theory, is thus called for.

Infrastructure and space

A linked set of ideas, specifically about the spatial organisation of infrastructures, lie within STS work and are mobilised in this thesis to help deal with the challenge of studying the constitution of demand in Central Manchester. Within the STS tradition scholars have studied and shown how various networks take shape simultaneously at different spatial scales and for different reasons (Winner, 1980; Hughes, 1983; Summerton, 1992; Latour, 1996). At the core of such works lies a common interest in conceptualising and studying infrastructural change over time (Winner, 1980; Hughes, 1983, 1987; Mayntz and Hughes, 1988; Summerton, 1992; Latour, 1996).

Working with systems, or parts of a system, as their units of enquiry, scholars have described how physical geographies affect and inform the development of service networks (Hughes, 1983; Moss and Francesch-Huidobro, 2016). As Hughes explains (1983, pp. 405 - 406):

> Of the circumstantial factors that shape the style of a regional system, geography is the most obviously influential. Seasonal variations in daylight, the location and character of rivers, lakes and seas, the availability of mineral deposits, soil and vegetation, [and] elevations… [shape] the character of electric power systems.

Adjoining this appreciation for how physical geographies affect the development of systems, is a particular sensitivity of the effects of a setting's social and political landscape (Winner, 1980; Hughes, 1983; Summerton, 1992; Latour, 1996; Guy et al., 1997; Graham and Marvin, 2001; Harrison, 2013). Within his seminal study Hughes' (1983) describes, for example, how the electrification of different cities in America and Europe imitated the economic and political nuances of specific sites. For instance, the early development of London's electricity network reflected a fragmented pattern of generation and distribution, synonymous with a haphazard approach to granting multiple licences within the same geographic territory (Hughes, 1983). By contrast, Hughes (1983) suggests the electrification of Chicago was smoother and homogeneous as a consequence of the creation of a spatial fix, within which one company was granted monopoly control over generation and supply (Hughes, 1983).

Echoing Hughes' (1983, 1987) concern for the relationships between the social and political landscapes of cities and their infrastructural networks, a specific body of work has developed around a detailed consideration of the management and organisation of urban infrastructures (Guy et al., 1997; Graham and Marvin, 2001; Moss, 2008; Guy et al., 2010; Graham and McFarlane, 2015). Contributors within this field of work take the city as their starting point and frame of reference. A key theme and concept within the urban infrastructure canon is 'unbundling', which concerns processes of liberalisation and the privatisation of service networks and space (Guy et al., 1997; Graham and Marvin, 2001). Graham and Marvin (2001) have specifically written at length about the splintered geography of service provision and land use.

A similar political focus has formed a central theme within socio-technical transitions studies, which draw on and operationalise the multi-level perspective (MLP) - a complete analytical framework with roots in evolutionary economics (Geels, 2002, 2005). In contrast to focusing on the city or urban processes, the propensity within works influenced by MLP has been to focus on the political management and organisation of nation-state systems (Correljé and Verbong, 2004; Geels, 2005; Verbong and Geels, 2007, 2010; Geels et al., 2016; Olufolahan et al., 2018). As Hodson et al. (2017, p. 1) note: 'analysis [of] national systems… dominates the socio-technical transitions literature'. Accordingly, infrastructural change and development tends to be framed within a national setting and interpreted as a product of the political, social and cultural nuances of such settings.

The tendencies to focus on the effects of the situated material geography and the social, political and economic organisation and management of infrastructures, at either the scale of the city or the nation-state, leaves questions open about the multi-scalar ordering of social-material networks. Questions specifically remain open regarding how infrastructures are managed across space, as extended formations that tend to stretch beyond the political boundaries of cities and nation-states. Infrastructures of gas, water, electricity, telecommunications, rail and, inter alia, roads, are clearly spatially extended formations, which lead in and out of the jurisdictional bounds of different cities and countries. This physical extension sees many service infrastructures simultaneously caught up in and affected by the politics of different governing bodies and organisations. Yet, the tendency to mobilise either the urban or the national political scale, as the unit and frame of analysis, leaves questions open regarding how infrastructures are managed, simultaneously, across space and according to the mobilisation and enactment of particular spatial scales.

Questions concerning the relationships between everyday practices and the organisation of large-scale infrastructures are also opened up as a consequence of the tendency within STS influenced studies to focus on the technical emergence, development and management of specific systems. As Furlong (2014, p. 144) suggests, within studies concerning large-technical systems there is a tendency to ignore 'how systems are continually remade through everyday interactions'. Instead, the role of 'system builders' and/or the direct influence of other human and non-human actors, in relation to an infrastructure's change over time, have been emphasised (Winner, 1980; Hughes, 1983, 1987; Latour, 1988, 1996; Summerton, 1992). In combination with the propensity to foreground a particular spatial resolution and frame, the tendency to focus on specific actors and their influence, in terms of shaping a system's development, leaves open questions about how an infrastructure's management and organisation relates to the ordering of everyday practices, as they occur across space.

In response to the open questions outlined, a diverse set of starting points and methods are called for in order to study the spatial constitution of electricity demand at different scales and as an outcome of relationships between practices and infrastructure. I now explain why the 'city' represents a particularly topical, relevant and appropriate site and starting point to begin such an investigation.

The 'city'

Following others interested in the organisation of large-scale networks, I take the city as my starting point. Cities have long formed the logical starting point for a great deal of research concerning various networks (Hughes, 1983; Guy et al., 1997, 2001, 2010; Graham and Marvin, 2001; Moss, 2008; Brook and Dodge, 2012). Shove (2016) suggests that this tendency is, at least in part, due to the types of questions asked by scholars and their interest in the political and economic ordering of infrastructures. Given such interests, the dense knots of infrastructure, which are clearly caught up in and affected by the political and economic organisation of cities, render the city a logical and nicely bounded starting point for research. For others, the decision to start in the city arguably reflects a strongly held conviction that urban processes and the metabolism of the city lie at the heart of infrastructural change (Tarr and Dupuy, 1988; Coutard et al., 2004; Gandy, 2004; Monstadt, 2009).

My decision to take the city as my starting point is not, however, simply a product of recognising that cities have formed the logical starting point for scholars interested in the management, organisation and development of networks. My decision to start in the city is also directly a product of my research questions and the key aims of this thesis. In this respect, starting with and in the city supports my task in different ways.

Firstly, cities can be usefully conceptualised as 'global-local' formations, cross-cut, shot through and shaped by a multitude of intersecting trajectories (Massey, 1991, 2005; Amin and Thrift, 2002). This conceptualisation renders the city a particularly useful starting point and site to study the situated and the simultaneously distributed relations that underpin the spatial anchoring of practices, and the connections between bundles of practices and the electricity network. The city, in turn, offers a particularly pertinent place to study and unpack the spatial constitution and dynamics of demand.

Secondly, cities are simultaneously caught up in multiple political, economic and social frames of reference and spatial scale, which affect and shape their development over time (Massey, 2009; Chowdhury et al. 2011; Giovanardi, 2015). This is to say that cities are caught up in multiple relational spatial scales and that their management and change over time relates to political, social and economic processes, enacted in accordance with such scales (Chowdhury et al. 2011; Giovanardi, 2015). This understanding hinges on a relational conceptualisation of scale; a conceptualisation which recognises 'scale as a social construct' that is real in its effects (Giovanardi, 2015, p. 611). For example, cut into every city are quarters and districts, known for what they offer in comparison to each other, which is generally a derivative of the types of activities that take place within each area (Bennison et al., 2007). The city itself also acts as a common frame and scale of reference, which is mobilised and enacted, as part of the ongoing work of various political actors and scholars (Guy et al., 2001; Bulkeley et al., 2014; Carter et al., 2015; C40, 2019; Core Cities UK, 2019). Zooming out, cities are also caught up in metropolitan regions, as well being entangled in wider geographical scales, such as the nation-state and other international frames. Working with the city thus immediately provokes and opens up opportunities to think through and study how the enactment of different spatial scales relates to and affects the organisation of the city (in terms of the use of land) and connected infrastructures (in the case of this thesis, the electricity system). The city thus suitably represents a particularly logical starting point to engage with, analyse and study the constitution of electricity demand at different scales.

Crucially, the city only opens up such opportunities because it is conceptualised and approached, throughout this thesis, as a relational construct, which is beset by multiple 'global-local' trajectories and simultaneously caught up in various spatial scales (Massey, 1991, 2005; Amin and Thrift, 2002; Giovanardi, 2015). This treatment of the city bears stark contrast with the tendency to treat cities as isolated and contained empirical units, which overlooks and presupposes how the 'city' is a 'structural product of social practices and political strategies'

(Brenner, 2013, p. 109). As opposed to forming a contained unit, the 'city' is mobilised here as an entry point for opening up and following lines of enquiry concerning how electricity demand is constituted and managed at different scales. Thus, although I start in and with the city, I do not stay there.

Central Manchester

The 'city' is, of course, a generic term; there are many cities and they are not the same. A measured and practical decision had to be taken regarding which city and thus which strategic research site to work with. As Bijker et al. (1987, p. 192) note, the choice of suitable 'strategic research sites' is particularly crucial within studies concerning socio-technical arrangements, such as infrastructures:

> Part of the task of… technology studies is the identification of research sites at which the complexity of the seamless web is manageable but which at the same time serve to capture key aspects of technological development. We call such locations strategic research sites.

Recognising the importance of choosing a suitable strategic research site, I chose a city which particularly fitted with and reflected the main aims, themes and questions of this thesis. It specifically made sense to select and work with a city that had experienced a concentrated period of change in its spatial use and composition. It also made sense and was necessary to focus on a city for which relevant data and sources were available and accessible. Working with relevant data and focusing on a city that had experienced a marked period of change promised to provide opportunities to trace out and explore the city's 'global-local' formation, and how the city's change over time related to and affected the management and organisation of the electricity system.

In light of the reasons noted, Manchester offered a particularly relevant strategic research site. As discussed in Chapter one, Manchester has experienced pronounced economic and population growth over the past four decades (Williams, 2003; Harding et al., 2010; Rae, 2013; Thomas et al., 2015; Deloitte, 2018, 2019; Elliott, 2018;). Such changes, which have been concentrated in the centre of the city, have involved the changing form and function of land and further seen Manchester become a focal point of research concerning processes of urban regeneration (Williams, 1996, 2003; Quilley, 2000, 2002; Peck and Ward, 2002; Ward, 2003; Montgomery, 2005; Harding, 2010; Rae, 2013).

Given Manchester's development and change, over the past four decades, it is a particularly pertinent site to study how the constitution of electricity demand takes shape at different scales. Additionally, an abundance of relevant data and secondary literature is available concerning the city's development and change. Accordingly, Central Manchester represented and provided a particularly appropriate and practical starting point and strategic research site to explore the themes and research questions of this thesis.

Electricity infrastructure

As with my decision to start in Central Manchester, my decision to focus on the electricity system reflects the key concerns of this thesis. The electricity system that supports Central Manchester is a geographically dispersed arrangement, which stretches out beyond the city and across Europe, and is owned, managed and maintained by several organisations (ENTSO-E, 2017, 2018a, 2018b; OFGEM, 2018, 2019). The system is, like Manchester, simultaneously caught up in multiple relational scales. Focusing on the electricity system therefore affords opportunities to consider spatial themes, including dispersed and different forms of interconnection between practices and hardware, and further how such electricity hardware is materially and institutionally configured at various scales.

My decision to focus on the electricity system was also informed by a practical recognition that Central Manchester's contemporary development has depended greatly on electricity. Contemporary population growth in the city centre has seen Manchester's urban core become a residential hotspot (Deas et al., 2000; Rae, 2013). This residentialisation has relied greatly on the provision of electricity, with 85-95% of properties in Manchester city centre not on the gas network (Non-Gas Map, 2018). Recognising that a major aspect of Central Manchester's contemporary development has hinged on the provision of electricity further provoked a focused consideration of the relationships between the city's development and the electricity system. Additionally, the expected growing dependence on electricity, as a means of achieving climate change goals, also informed my decision to focus on the organisation of the electricity system (Franco and Sanstad, 2008; Breukers et al., 2013; Goulden et al., 2014; United Nations, 2015).

Four empirical studies

To investigate the constitution of electricity demand in Central Manchester, I designed four different studies (Figure 5). The design and application of four separate studies takes inspiration from Mills (1959). As Mills (1959, p. 126) notes:

> The… craftsman does not usually makeup one big design for one big empirical study. His policy is to allow and to invite a continual shuttle between macroscopic conceptions and detailed expositions. He does this by designing his work as a series of smaller-scale empirical studies…, each of which seems to be pivotal to some part or another of the solution he is elaborating.

In this regard, the research design of this thesis and my use of four studies represents a considered attempt to meet the challenge of studying the relationships in and between practices and the electricity system across space and at different scales.

Responding to the methodological challenge of 'seeing' the constitution of electricity demand at different scales, each of the studies described below does not conjure up another piece of the same empirical puzzle. Instead, each study generates a different set of insights regarding the constitution of electricity demand and the relationships between practices and the electricity system - insights which are directly the product of the application of a specific set of methods. In this way, the studies show how the mobilisation of particular techniques constitute different depictions of how practices and the electricity system relate, as well as providing examples of how such relationships can be conceptualised and studied at different scales.

The development of four different studies also follows Cerwonka and Malkki's (2007, p. 14) proposition that knowledge production hinges on the adoption of 'approaches and tools as a consequence of the questions being asked [and] not as a consequence of the methodological constraints' dictated by a particular theoretical position. In this respect, my research questions demanded the adoption of techniques that appropriately supported an exploration of the spatial relationships between practices and the electricity system. They also demanded engagement with concepts and ideas outside of those typically deployed and worked with by those within practice theory. Such engagement does not signal any deficiencies on the part of practice theory but rather an attempt to work with conducive ideas, which are mobilised to address previously unexplored questions.

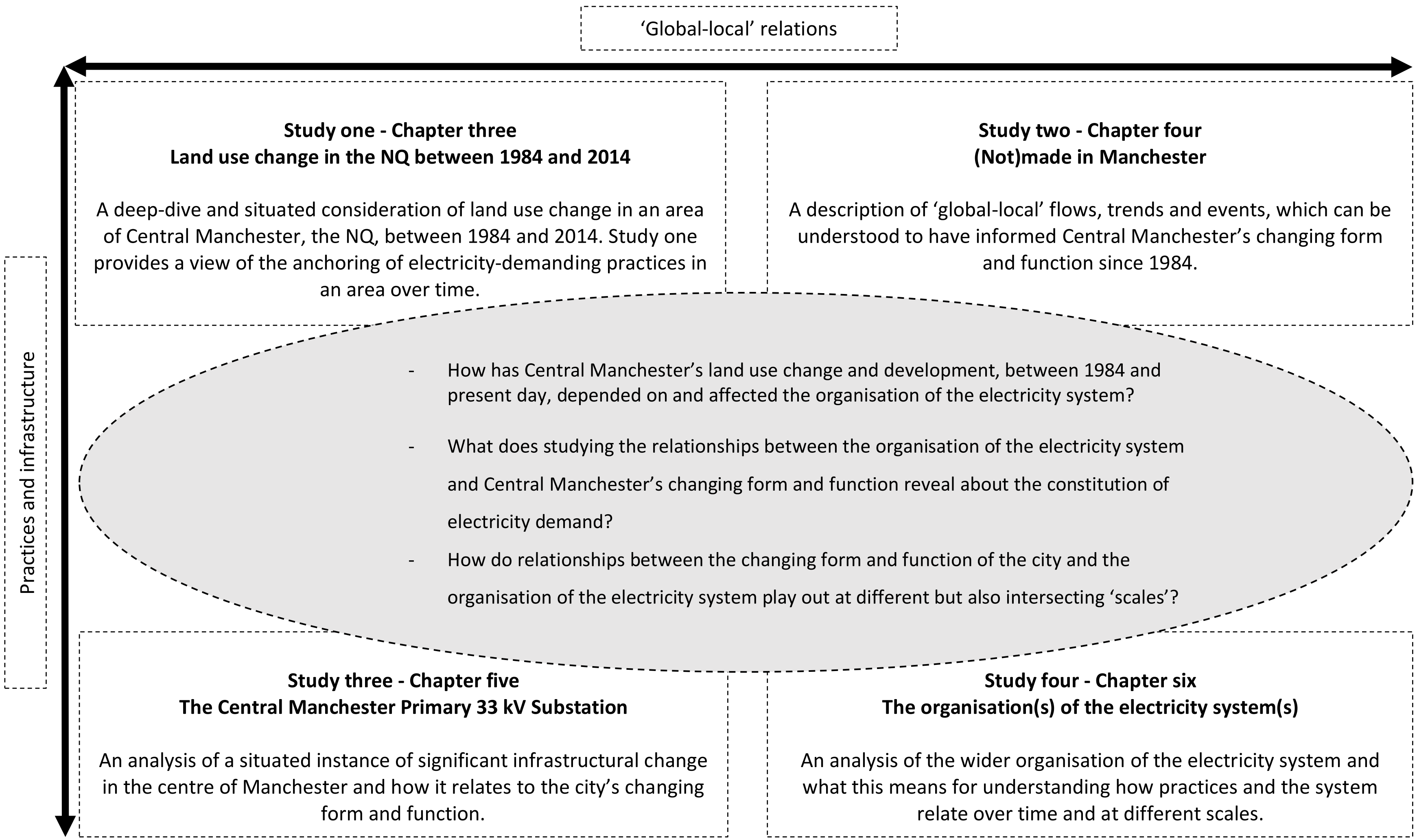

Figure 5: Research design diagram

Study one: Chapter three - Land use change in the Northern Quarter (NQ) between 1984 and 2014

The design of Study one represents a direct response to meeting the challenge of identifying and tracking the changing composition of electricity-demanding practices in the city over time. My response to this challenge pivots on two steps.

Firstly, to tackle the challenge of tracking the changing composition of electricity-demanding practices in the city, I work with Land Use Change Statistics (LUCS) generated between 1984 and 2014, mobilising land use categories as proxies for 'practice bundles' (Schatzki, 2011; Shove et al., 2012). By working with land use change categories as proxies for practice 'bundles', I take instances of land use change as markers of the shifting constitution of electricity demand in an area over time.

A practice bundle is understood to form 'a set of linked practices' (Schatzki, 2011, p. 8), 'co-located in space and/or time' (Shove et al., 2015, p. 8). Working with this conceptualisation, I interpret land use categories, such as 'Residential', 'Industry', 'Offices' and 'Retailing', as proxies for practice bundles. For example, the land use category 'Residential' is taken to represent a bundle of practices that typically take place in the home. Inter alia, practices of heating, cooking, cleaning, watching tv and working are understood to form the loose-knit 'Residential' bundle. Likewise, it is possible to imagine the practice bundle that comprises 'Offices'. Inter alia, computing, space heating and meetings are, for example, activities that commonly connect in and help to form an office setting and can be further understood to constitute parts of the practice bundle that the land use category 'Office' is taken to represent in this thesis.
Working with land use categories as proxies for practice bundles has specific drawbacks. For example, what constitutes an office changes over time (Cass, 2018). The diffusion of various technologies, for example, computers, have seen offices become physically different working environments to what they were

before the arrival of such artefacts. Similarly, practices that comprise a residential bundle shift over time, both in terms of change in the composition of particular practices and in terms of the introduction of new forms of activity into the home (Spurling, 2015). The diffusion of the TV, for instance, has depended on the home becoming a site of watching, which further hinges on a reconfiguration of living rooms (Spurling, 2015). Land use categories hide such changes over time.

These deficiencies acknowledged, working with land use categories as proxies for bundles of practice still proves a useful means of tracking broader shifts in the electricity-demanding use of land over time. Moreover, working with land use categories as proxies for bundles of practice provides a means of generating specific questions about how a particular place's change over time, in terms of trends in the changing composition of practices in an area, affects, relates to and depends on the organisation of the electricity network.

The second step taken, as part of Study one, sees the Northern Quarter (NQ) mobilised as a 'strategic research site' and starting point (Bijker et al., 1987). This move builds on Guy et al.'s (1997), and Graham and Marvin's (2001) proposition that cities are 'splintered' formations comprised of different areas, with fragmented forms of infrastructural access and specific material histories. To engage with such ideas, I decided to focus on the NQ's land use change between 1984 and 2014. This move opened up an opportunity to consider the constitution of electricity demand in a part of the city centre, and further a chance to consider how the changing form and function of this particular area affected and depended on the ordering of the electricity system.

The NQ offered a particularly useful starting point because, in contrast to other areas in the city centre, the NQ's change and development was not part of a larger regeneration masterplan (Wansborough and Mageean, 2000; McCarthy, 2006). In contrast to other areas in Central Manchester, such as Castlefield, the Green Quarter, Hulme, East Manchester and Ancoats, 'no overall redesign strategy' was developed for the NQ (Wansborough and Mageean, 2000, p. 194). Indeed, the area's development is typically framed as an outcome of the combined activity of local commercial actors, artists and Manchester City Council, and not as a product of grand masterplans or blueprints, designed and signed off by the local authority (Wansborough and Mageean, 2000; McCarthy, 2006). The NQ, in turn, provided opportunities to study the unique and not centrally planned development and anchoring of electricity-demanding practices in a quarter of Central Manchester over time, and further an opportunity to question how a particular city quarter's development affected and depended on the electricity network.

The two methodological steps taken as part of Study one enable a set of insights to be generated regarding the changing and uneven constitution of electricity demand in the NQ between 1984 and 2014. The insights regarding the NQ's land use change are also crucial to and taken up in subsequent empirical chapters. For example, in Chapter four, I consider the trends that affected the NQ's land use change and Central Manchester's broader development since 1984. Switching focus to the organisation of electricity hardware, in Chapter five, I consider how an example of large-scale infrastructural investment, which coincided with a spike in the NQ's development (derived as a consequence of conducting Study one), relates to the area's and the city centre's contemporary change.

Study two: Chapter four - (Not)made in Manchester

Study two represents a considered effort to conceptualise and understand what affected and informed the NQ's land use change and Central Manchester's wider development since 1984. This study builds on an understanding that cities are 'spatially open and cross-cut by many different kinds of mobilities, from flows of people to commodities and information' (Amin and Thrift, 2002, p. 3). Working with this understanding and drawing on Massey's (1991, 2005) work, I make a series of connections between specific 'global-local' intersections, trends and events and Central Manchester's land use change since 1984. Specifically, as part of Study 2, I introduce and work through three 'global-local' dimensions of Central Manchester's land use change between 1984 and the present day. Firstly, I describe the changing political landscape of planning policy. Secondly, I describe the 'global-local' flows connected with the city centre's residentialisation. Thirdly, I consider the effects of two international events - the 1996 IRA bomb and the 2002 Commonwealth Games – on the city centre's form and function.

My decision to focus on the first and third dimensions was informed by a body of scholarly work which points to, but does not strictly consider, the related effects of the broader (inter)national context of planning and the impact of the IRA bomb and the 2002 Commonwealth Games on the city centre's development and land use change (Deas et al., 2000; Holden, 2002; Peck and Ward, 2002; Cook and Ward, 2011). In contrast to previous work, which has tended to explain Manchester's contemporary development as a consequence of the local authority's entrepreneurial approach to governance and further focuses on particular events in isolation, I draw connections between the changing (inter)national planning context and the advent of specific international events in relation to the city's land use change over time. As opposed to the first and third dimensions, my decision to focus on Central Manchester residentialisation was informed by the trends and changes in land use revealed as a consequence of conducting Study one and more broadly as an outcome of acknowledging Manchester city centre's well-documented population growth since the turn of the millennium (Williams, 2003; Rae, 2013; Swinney and Carter, 2018).

The 'global-local' dimensions of Central Manchester's land use change were studied using the following methods:

- Interviews[5]: Study two is informed by five in-depth expert interviews[6]. All of these were with planning and regeneration practitioners employed by Manchester City Council (MCC) and/or other relevant development agencies over the timeframe considered. Specifically, I interviewed Dan, a planning professional with over forty-two years' experience working within MCC's Planning Department, in various capacities. Dan's participation was a product of my discussions with members of the planning team during visits to view planning applications. Members of the team suggested Dan was the best person to speak to regarding the longer-term development of the city centre, due to his tenure and experience. I also interviewed Tony, who has worked in urban regeneration since 1980, as a consultant, a member of MCC's planning department and as a part of English Partnerships (a regeneration agency). Tony offered specific insight and expertise regarding the 'politics of partnership', strongly linked with Manchester city centre's regeneration in academic literature (Peck and Ward, 2002; Evans, 2007). John, an interviewee with over forty years' experience working within urban regeneration, whom I interviewed twice, instead provided detail regarding how capital was coalesced around specific projects and events, including the 1996 IRA bomb and the 2002 Commonwealth Games. A major part of John's career was spent as a proposal writer, seeking development monies for MCC, between 1988 and 2000. By contrast, Jane was chosen because of her experience working within MCC's Planning Department for over fifteen years. As a current member of the planning team, Jane provided detail regarding the contemporary effects of particular planning policies and spatial plans in the city centre.

[5] Appendix 1 contains a copy of the Participant Information Sheet used as part of this PhD.
[6] Pseudonyms are used throughout this thesis and little reference is given to the exact role or position held by interviewees.

- A review of secondary sources: In order to develop an understanding of the broader legislative context within which the city centre's form and function has changed, I also studied nineteen local and national planning policies, strategies, acts and reports, covering a period between 1945 and 2012. Several of these plans, strategies and official publications relate to the recovery from the IRA bomb and the delivery of the 2002 Commonwealth Games. A list of the documents reviewed as part of Study two is presented in Appendix 2. Finally, to better understand Manchester city centre's residentialisation, I consulted a number of secondary sources concerning Buy-to-let mortgage legislation and data concerning rates of private homeownership, student numbers, and the privatisation of higher education.

The relatively small number of interview participants selected to inform Study two, reflects a commitment to gaining detailed insights from planning practitioners with extensive experience working within Central Manchester over the past four decades. The participants' combined knowledge greatly supported and supplemented my study of what informed and shaped the NQ's land use change and Manchester city centre's broader development over this period.

A unique set of insights regarding the spatial constitution of electricity demand in Central Manchester are articulated as a consequence of conducting Study two. 'Without the pretence of [providing a] total sight or generalization', Study two draws attention to 'global-local' intersections, trends, and events that inform the spatial ordering of electricity demand over time (Amin and Thrift, 2002, p. 26). The account articulated as a consequence of conducting Study 2 also provokes thought regarding where electricity demand is made. While studying the NQ's land use change between 1984 and 2014 (Study one) provides a situated account of the constitution of electricity demand, conceptualising and examining Central Manchester's 'global-local' formulation (Study two) suggests demand is a dispersed phenomenon. Switching away from the dynamics of land use change, the following studies are about the material organisation of the electricity network.

Study three: Chapter five - The Central Manchester Primary 33 kV Substation

Picking up on the land use changes revealed as a consequence of Study one and following a rich tradition within STS of focusing on a particular network (Winner, 1980; Hughes, 1983; Summerton, 1992; Latour, 1996), Study three involves an examination of the £1.8 million 2009 development of the Central Manchester 33 kV Primary Substation (Independent Quality Surveyors (IQS), 2017). The Central Manchester Primary, which is closely located to the NQ and connects with Low Voltage (LV) 6.6 kV substations in the area, is one of seven primaries in the city centre. It is also one of only two 33 kV substations built in the centre of Manchester since 1972. The Central Manchester Primary therefore represents a relatively rare instance of extension to the city centre's high voltage (HV) network. Study three specifically involves a consideration of why this instance of network extension occurred in 2009, and how the development of the Central Manchester Primary connects with the NQ's land use change and Central Manchester's changing form and function since 1984.

I decided to focus on the Central Manchester Primary's development as a consequence of reviewing 33 kV load data profiles, provided by Electricity North West (ENW), and realising that the substation was commissioned in 2007 and completed in 2009. Having realised that the Central Manchester Primary represents a rare instance of large-scale investment in the city centre's distribution network, which dovetailed with Manchester city centre's increasing residentialisation and commercial development (links revealed as a consequence of conducting Study one and Study two), I decided to study the substation's emergence.

To understand why the substation was built and to gain an understanding of the organisation of ENW's distribution network, I employed the following methods:

- Expert interviews: I conducted eight expert interviews with ENW electrical engineers, planners, contract officers and connections managers. Specifically, I interviewed Diana[7], an ENW employee with over thirteen years' experience, who provided detail regarding how the network's future is envisioned and modelled. Building on similar themes, Karen, Malik and Tim, who have a combined forty-four years working within the industry, discussed the current and future organisation of the company's network and the challenges faced by changing patterns of electricity demand. Steve, an engineer with thirty-three years' experience, instead provided insight about the day-to-day management of Manchester city centre's network. I interviewed Steve twice, once in the office and on the other occasion during a private walking tour of the Bloom Street Bulk Supply Point (BSP). The walking interview provided useful insight regarding the mechanics of distribution. Alan, a connections specialist, with over fourteen years' experience, who I interviewed twice, specifically explained how new applications for connection are handled and how the connections process had changed over time.

- Participation in ENW events: I attended two annual stakeholder meetings and participated in three smaller advisory panels concerning the future organisation of the network. Participating in these events provided detail regarding how challenges are framed within ENW and how the company presents its management of the network.

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[7] Pseudonyms are used for all Electricity North West employees. Also, to maintain anonymity, I do not provide specific detail regarding exact job roles.

- Secondary sources: I examined various secondary sources, including planning applications, design proposals and schematic diagrams linked with the Central Manchester Primary's 2009 development (Manchester City Council, 2007; IQS, 2017).

Working with these methods, I position and explain the development of Central Manchester 33 kV Primary in reference to two explanatory 'technological frames' (Bijker, 1995). The first frame concerns here-and-now challenges and threats to network capacity linked with new applications for connection. The second frame sees longer-term future projections and expectations of electricity demand in the 'city' a key factor of investment. As a consequence of conducting Study three, detail is generated regarding how the constitution of electricity demand, in relation to shorter and longer-term patterns of land use change and the broader changing form and function of the city centre, depends on and affects the situated and material organisation of the electricity network. Additionally, by conducting Study three, I show what can be gained from investigating an instance of network extension in order to explore the spatial relationships between practices and the electricity system. By making this move and studying the relationships between practices and the electricity network in the fashion described, I provide new methodological insight and empirical detail regarding the material constitution of demand and how it is handled.

Study four: Chapter six - The organisation(s) of the electricity system(s)

Study four is shaped around two acknowledgments: firstly, that Central Manchester is supplied by a geographically stretched socio-material electricity system; secondly, that the Central Manchester Primary forms a part of this system. Acknowledging these points, I raise and address the following questions:

- How does Central Manchester's land use change relate to and depend on the wider organisation and management of hardware that supplies electricity?

- How does investment in specific network assets, such as the Central Manchester 33 kV Primary, relate to the management of the electricity system at different spatial scales?

- What does studying the organisation of the hardware that supplies electricity to Central Manchester, at different scales, reveal about the constitution of electricity demand?

I address these questions by focusing on representations of the electricity system produced by organisations involved in the ordering of infrastructure that supplies electricity to Central Manchester. This examination of the network's organisation is specifically informed by a detailed review and analysis of twelve Manchester-specific energy plans and a collection of network-orientated documents, maps, diagrams, proposals and reports produced by organisations directly involved in the electricity system's management (Appendix 3 provides a list of the main documents worked with as part of Study four). The organisations include Manchester City Council (MCC), the Association of Greater Manchester Authorities (AGMA), the Greater Manchester Combined Authority (GMCA), Electricity North West (ENW), National Grid (NG), National Grid Electricity Transmission (NGET) and the European Network of Transmission System Operators for Electricity (ENTSO-E).

Working with the sources noted, I mark out three different 'professional worldviews' (Ellis, 1996) of the electricity system, which are constituted through the work of the organisations referred to. I suggest that each view of the network is real in its effects, which is to say that they are enacted. As a consequence of drawing attention to the enactment of multiple views and versions of the electricity system, in relation to the spatial jurisdictions of particular organisations, I show how scale is 'implicated in the production of space', demand and electricity infrastructure (Marston, 2000, p. 220).

As a consequence of discerning different organisational views of the electricity system, I provide a different set of insights regarding the constitution of demand and the scalar relationships between practices and the electricity system. Intriguingly, the analysis that results as a consequence of conducting Study four sees Central Manchester's land use change and the broader changing form and function of the city take up ambiguous positions, slipping in and out of relevance in regards of the network's organisation and change over time.

The implications of conducting four studies

I began this chapter by explaining the epistemological roots of the thesis. I explained that the thesis is built on the premise that the methods used to study a phenomenon constitute the phenomenon examined and the insights generated (Latour and Woolgar, 1979; Barad, 2003; Cerwonka and Malkki, 2007; Sayer, 2010). By implication, each study, by signalling the mobilisation of a different set of techniques, also produces a particular set of insights regarding the spatial constitution of demand and the spatial relationships between practices and the electricity system.

For example, by focusing in on the NQ (Study one) and an instance of infrastructural change (Study three), situated and spatially anchored insights of the relationships between practices and the electricity network are foregrounded and produced. Accordingly, electricity demand appears to be an outcome of the situated and contingent ways a place and its infrastructures develop in relation to each other. By contrast, Study two provides a different set of insights. Instead, spatial change and thus the geographic organisation of electricity-demanding practices are approached and studied as outcomes of broader 'global-local' trends and events which intersect, informing and shaping

Central Manchester's form and function over time. By implication, the city's electricity demand appears not to be a situated product of the city.

As a consequence of focusing on the wider organisation of the system, Study four leads to another set of insights regarding the spatial organisation of demand and the relationships between practices and the electricity system. Instead of emphasising local connections, the relationships between practices and the network change shape depending on the scale of analysis and the consideration of the representational work of different organisations involved in managing the network's hardware. Accordingly, and as a consequence of conducting four separate studies, I articulate four different accounts of the constitution of electricity demand, how it is enabled, and how it is handled at different scales.

Summary

In this chapter, I have explained how and why this thesis focuses on and examines the constitution of electricity demand at different scales by exploring the spatial relationships between practices and the electricity system. The relationships are configured and studied through the mobilisation of four different studies. Although each study emphasises a unique set of insights regarding the relationships between practices and the electricity system, a brief consideration of the ways the studies connect also shows how the different pieces of this thesis fit together and link in specific combinations. These combinations reflect the logic of the thesis.

Reading the box diagram which represents the thesis' research design horizontally (see Figure 5), Study one and Study two, in combination, provide detail regarding the 'global-local' changing form and function of the NQ and more broadly Manchester city centre since 1984. In conjunction, these studies articulate a picture of electricity demand as a formation that emerges as a consequence of intersecting practices and related policies, trends and events, which shape and inform a city's change over time. This picture is articulated as a consequence of Study one providing detail regarding the circulation and anchoring of practice bundles in a locale over time, and Study two emphasising the wider trajectories that affect, inform and structure the flow and mooring of electricity-demanding practices in the city.

In contrast, Study three and Study four, in combination, foreground the heavy material and organisational relationships that exist between practices and electricity network. The material dimensions of the relationships between practices and the system are captured through my analysis of the development of the Central Manchester Primary (Chapter five), whilst also featuring in my analysis of the wider organisation of the network (Chapter six). Together, Study three and Study four thus show how the dynamic circulation and anchoring of practices, as foregrounded as a consequence of conducting Study one and Study two, depends on and informs the organisation of a geographically extended material network, which enables and responds to clumps of electricity-demanding practices at different scales.

Vertical synergies can also be drawn between the studies represented in the box diagram presented above (Figure 5). When read in combination, Study one and Study three foreground the situated relationships between the anchoring of bundles of practice and the extension and development of the electricity system. Although not exactly linear and clear-cut, Study one and Study three point to how the situated development of places, such as the NQ and Manchester city centre, and thus the spatial circulation and anchoring of electricity-demanding practice bundles, relates to, depends on and provokes similarly situated instances of electricity demand and infrastructural extension.

Continuing to work vertically, Study two and Study four together foreground how the spatial organisation of electricity demand is the outcome of a combination of practices, related aims and objectives, which intersect, over time, and are captured in the changing use of land and related instances of extension on the electricity network. This combination, in contrast to the others, provokes questions about how to conceptualise where and how electricity demand and the electricity network are made.

Independently and as a product of specific combinations, the four studies that comprise this thesis accordingly provide unique insights regarding what informs the spatial ordering of electricity-demanding practices, and how such an ordering relates to and affects the organisation and management of the electricity network at different scales over time. The studies and combinations also show how the mobilisation of particular modes of analysis configure an 'ordering of knowledge' (Cerwonka and Malkki, 2007, p. 10). The different orders of knowledge presented in this thesis, by implication, provoke thought regarding how best to conceptualise and study electricity demand.

Chapter three: Land use change in the Northern Quarter between 1984 and 2014

A central challenge of this thesis is 'seeing' and tracking how the composition of electricity-demanding practices changes in a city over time. This challenge is, in part, about getting to grips with the life of a city, patterns of urban development and the related geographical circulation and anchoring of practices, which clearly depend on and affect the organisation of the electricity network. A review of a schematic diagram representing the low voltage (LV) 6.6 to 11 kV electricity network that underpins Manchester city centre shows, for example, how new building developments tend to come with new substations[8]. Such links are further captured in planning applications, with spaces marked out for the housing of substations. The planning application for the Smithfield Building mixed-use development, which is in the Northern Quarter (NQ), provides a relevant example in this regard (MCC, 1995a). Likewise, other bulky pieces of networked hardware do not simply pop-up, they are, like all instances of infrastructural investment, built at particular moments and in specific sites, and have been shown to follow patterns of urban development (Hughes, 1983; Frost, 1993; Chappells, 2003).

Acknowledging connections between the spatial anchoring of practices in the city and instances of network extension suggests that one useful means of studying the constitution of electricity demand is to focus on the circulation and anchoring of electricity-demanding practices in the city over time. A method is thus called for which helps get at changing patterns of urban development and the related geographical circulation and anchoring of electricity-demanding practices.

[8] Figure 14 and Figure 15, which are discussed in Chapter five, provide a snapshot of ENW's 6.6 to 11 kV North Manchester network and represents the ordering of LV substations.

Meeting this methodological challenge, in this chapter I present one means of conceptualising and studying the circulation and anchoring of electricity-demanding practices in the city and capturing sight of the constitution of electricity demand. I articulate this view by working with Land use Change Statistics (LUCS) covering the period 1984 to 2014, and using land use categories as proxies for practice bundles (ONS, 2017a, 2017b, 2017c). By mobilising land use change categories as proxies for practice bundles, I am able to track how the use of an area of Manchester city centre changed over time and in a time-sensitive fashion. I show, for example, that the NQ has increasingly become a residential location. And, furthermore, that the area's residentialisation largely unfolded after the turn of the millennium. I also show how, over the period considered, there was a churning in commercial land uses, including to and from 'Retailing' and 'Offices', and, more broadly, how land use change accelerated in the NQ after 1998.

As explained in Chapter two, my decision to mobilise the NQ as a 'strategic research site' (Bijker et al., 1987, p. 192) and starting point was informed by previous work and those, such as Graham and Marvin (2001), who have shown how infrastructural provision is shaped by and shaping of the uneven development of cities. In contrast to other parts of the city, the NQ's development is typically framed as an outcome of the combined activity and relationships between local commercial actors, artists and MCC, and not as an outcome of a grand masterplan (Wansborough and Mageean, 2000; McCarthy, 2006). This history provided an opportunity to study how the emergence of electricity demand in an urban area, which was not rigidly master-planned, took shape and how such an area's development over time depended on and affected the organisation of the electricity system (questions taken up in Chapter five).

In the next section, I explain what the use of land use categories as proxies for practice bundles entails, as well as what this methodological move provides. Having provided this detail, I present and discuss how the NQ's land use changed between 1984 and 2014. In this chapter's summary, I sketch out a series of unanswered questions generated as a consequence of focusing on the NQ's changing land use between 1984 and 2014. These questions are taken up and explored in different ways in the other empirical chapters that comprise this thesis.

Land use change categories as proxies for practice 'bundles'

The empirical insights generated in this chapter involve the use of land use change categories as proxies for practice bundles. My mobilisation of land use change categories as proxies for practice bundles relates to the proposition that electricity demand is an outcome of the organisation and performance of social practices (Shove and Walker, 2014). Using land use categories as proxies for practice bundles provides a means of conceptualising and studying the circulation and anchoring of electricity-demanding practices in the NQ over time. To understand what my mobilisation of land use categories as proxies for practice bundles entails and represents, it is useful to firstly consider what land use categories signify and how and why land use change is tracked.

Although the tradition of tracking land use has a long history in the UK, the generation of full and consistent national Land Use Change Statistics (LUCS) only dates back to 1984 (Office of the Deputy Prime Minister (ODPM), 2004). Between 1984 and 2012 a particular methodology was used to collect LUCS (ODPM, 2004). From 2013 onwards, a new methodology for recording LUCS was adopted (Department for Communities and Local Government (DCLG), 2015). Although different methodologies underpin each dataset, in both cases, the generation of LUCS has been based on the use of specific land use categories.

Between 1984 and 2012, twenty-four different categories were used to organise and track land use change (ODPM, 2004). These categories were fitted into ten land use groups (ODPM, 2004), which were split between the broader classifications of ‘previously developed land’ and ‘non-previously developed land’. Likewise, LUCS generated since 2013 define land as either ‘previously developed land’ or ‘non-previously developed land’ (Department for Communities and Local Government (DCLG), 2015). However, due to the use of a new ‘cost-driven methodology’, four new categories of land use were introduced in 2013, alongside smaller changes to existing categories (DCLG, 2015, p. 10). Such differences render comparison between each dataset problematic (DCLG, 2015).

Although a different methodology underpins each dataset, the overall generation of LUCS reflects a similar rationale. LUCS are understood to provide valuable detail regarding patterns of development (ODPM, 2004; DCLG, 2015). They are further considered to be ‘of crucial importance to those developing, implementing or monitoring planning policies’ (ODPM, 2004, p. 2). LUCS have long been used, for example, to track and monitor the delivery of new housing and provide a measure of the UK government’s ability to stimulate the production of residential space (ODPM, 2004; DCLG, 2015).

While officially generated and used to monitor development and measure the success of planning policies, I instead mobilise LUCS to indicate the anchoring of electricity-demanding practice bundles in the NQ over time. The conceptualisation of practice bundles acknowledges that ‘practices connect and in so doing form complex systems or bundles that have something of a life of their own’ (Blue et al., 2016, p. 41). Bundles are also understood to be central to the production of space and the constitution of different sites (Schatzki, 1991, 2010a, 2010b, 2011). This understanding builds on Heidegger’s (1962) argument that the formulation of a place relates to the organisation of activity. Heidegger (1962) explains how tools in a workshop have a place: a portion of physical space which is assigned to them. Likewise, an individual home can be thought of as a physical space comprising a composite of places related to a residential practice bundle. Homes comprise, inter alia, electricity-demanding sites to work, to wash, to sleep, to leisure, and to prepare and consume food and drink. Read in these terms, the land use category ‘Residential’ represents a specific practice bundle, which marks out and constitutes the home. Similarly, land use categories, such as ‘Offices’ and ‘Retailing’, can be read as signs signalling the spatial anchoring of practice bundles related to two broader and different forms of commercial work, which depend on electricity.

Admittedly the use of land use categories as proxies for practice bundles is not without its limitations. My use of categories reifies the meaning of a practice bundle over the thirty years considered. This reification dissolves change over time in terms of what constitutes, for example, a home. The changing form or integration of new practices and related energy-hungry technologies into the home is overlooked (Spurling (2015) discusses such changes). Computers, laptops, tablets and mobile phones have, for instance, become key pieces of furniture in people’s homes over the past thirty years. The addition of these technologies can be taken to mark out changes in the composition of practices, which have long been a part of the home (such as watching, writing and communicating), or to represent the emergence and spread of new practices into domestic space, for example, internet shopping from the comfort of a sofa. Similar and different changes have also occurred in offices and other commercial spaces, with working practices changing and emerging over time (Hand et al., 2005; Cass, 2018). Such changes and developments are, of course, connected with changing patterns of electricity demand and are lost as a consequence of using land use categories as proxies for practice bundles.

These points noted, using land use categories as proxies for practice bundles also has benefits - particularly for this research project. The use of land use categories as proxies for practice bundles provides a means of seeing the circulation and specific anchoring of electricity-demanding bundles over time and in the NQ. With this insight, I am able to generate a series of more precise questions concerning the changing spatial use of the area and how such change depends on and affects the organisation and management of the electricity system. The mobilisation of categories as proxies for practice bundles thus provides a means of ‘seeing’ the spatial constitution of demand over time, while also providing a launchpad and means of generating questions that are taken up in subsequent empirical chapters.

Tracking land use changes in the Northern Quarter

The following accounts of the NQ’s land use change between 1984 and 2014 are the product of working with three datasets: 1) *Land Use Change Statistics 1984 – 2012* (ONS, 2017a)*;* 2) *Land Use Change Statistics 2012 – 2014* (ONS, 2017b); 3) *Residential Creations 2013 – 2014* (2017c)*.* Each of these datasets are collated by the ONS. As noted, between 1984 and 2012 a particular methodology was used to collect the data, with a new methodology employed in 2013. Subsequently, the Department for Communities and Local Government (DCLG) suggest ‘comparison and interpretation between the two series is not recommended’ (DCLG, 2015, p. 6). Heeding this advice, the trends highlighted in each dataset are considered separately in the sections that follow.

To map the NQ’s land use change between 1984 and 2014, I necessarily work with a specific bounding of the NQ. The boundary I use matches that used in a range of official maps developed by Manchester City Council (MCC) and Marketing Manchester - the ‘agency charged with promoting Greater Manchester on a national and international stage’ (Marketing Manchester, 2019) (Figure 6).

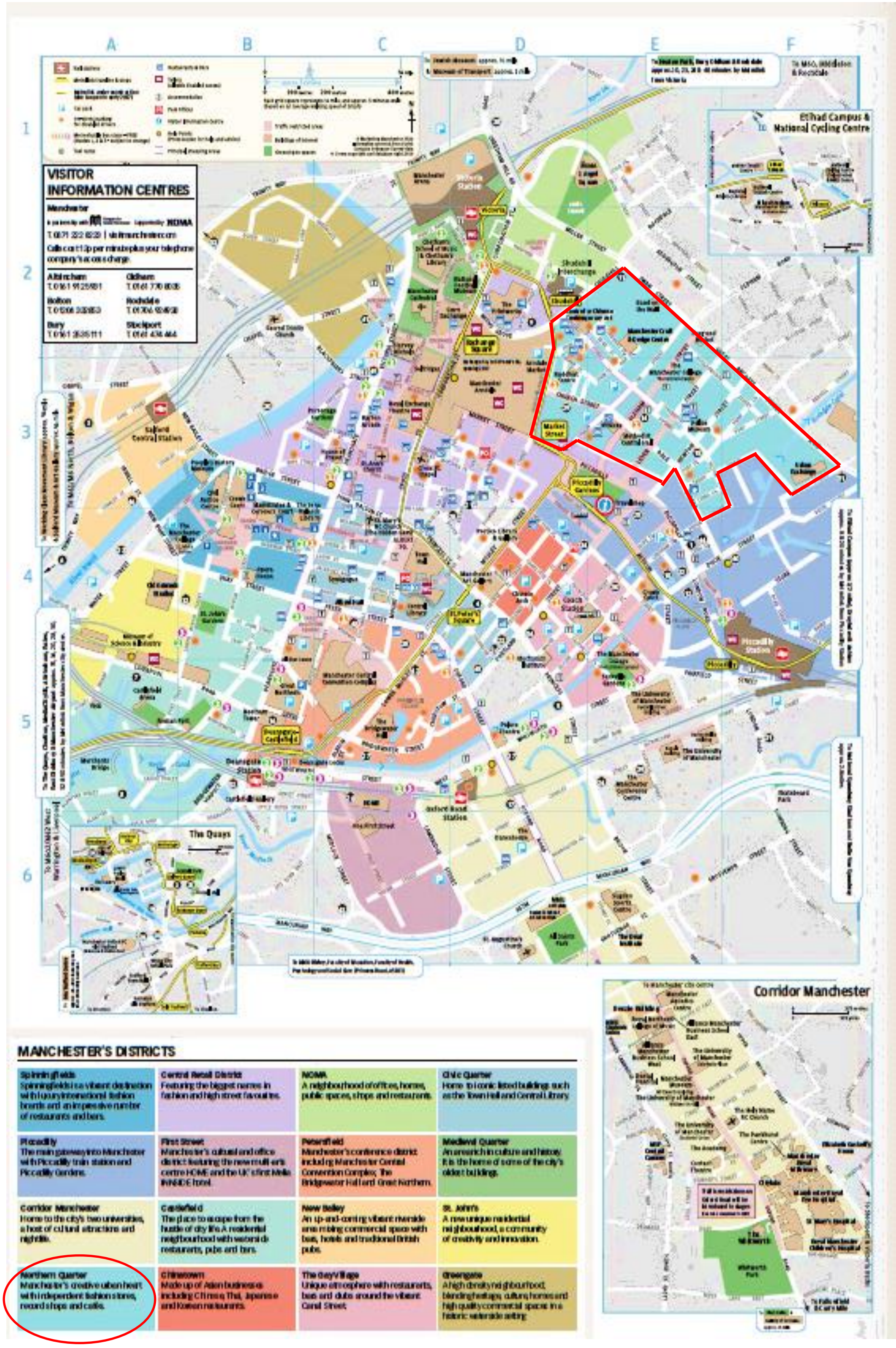

Figure 6: Map of Manchester city centre (Marketing Manchester, 2018)

Land use change in the Northern Quarter between 1984 and 2012

During the twenty-eight years between 1984 and 2012, sixty-three separate land use changes were recorded in the NQ. Figure 7 provides a representation of where the changes took place in the NQ. I generated this map using the geographical information contained in the LUCS 1984/12 dataset (ONS, 2017a). Appendix 4 explains exactly how I completed this task and the steps involved in plotting land use changes. The icons on Figure 7 represent types of land use change. The yellow house icons, for example, signal a change to 'Residential', the orange tower block icon, a change to 'Offices', and the purple handbag icon, a change to 'Retailing'.

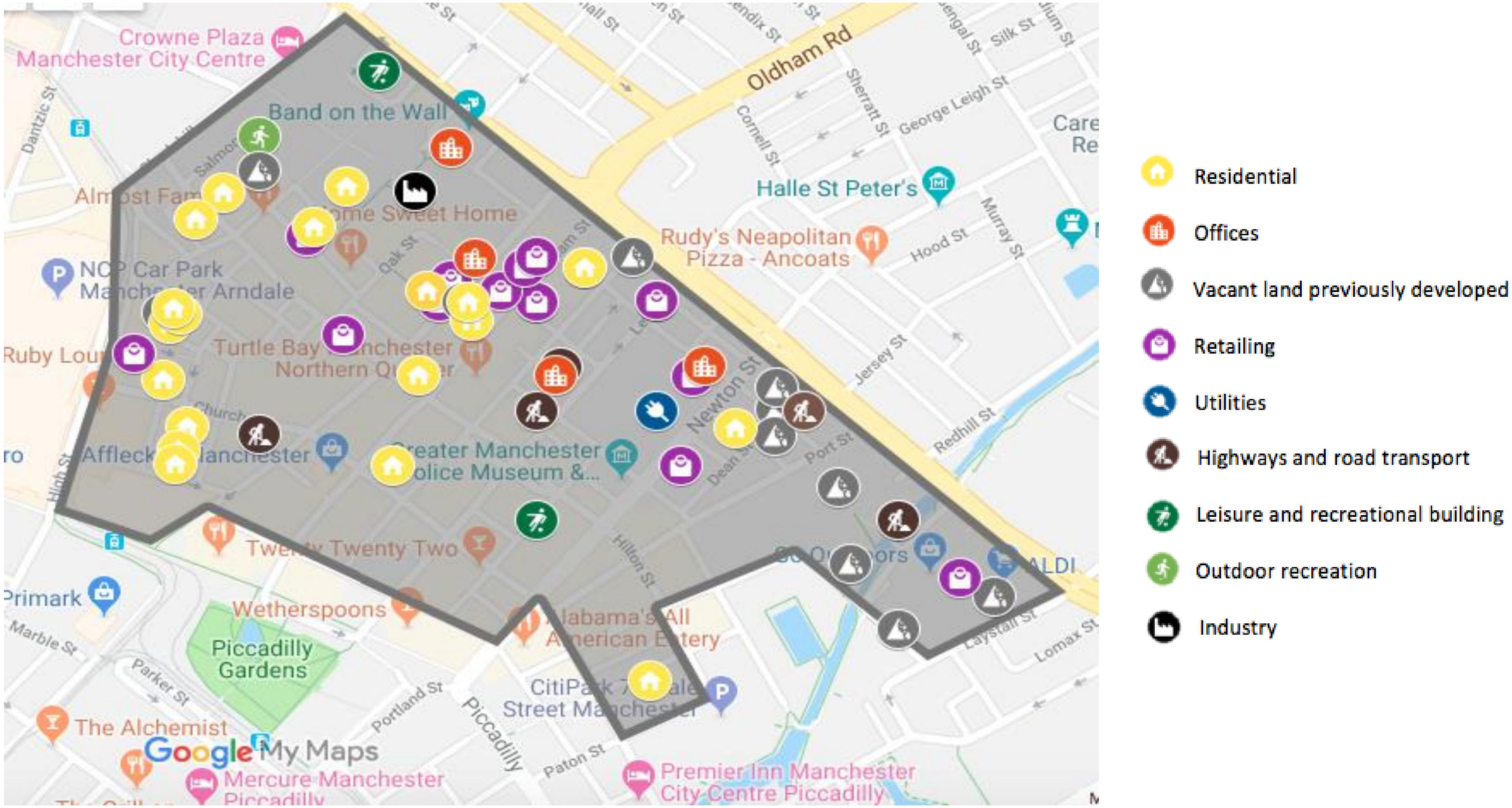

Figure 7: Changes to new land use in the NQ between 1984 and 2012

Between 1984 and 2012, a land use change was recorded when a parcel of land differed in any respect to its depiction on the most recent Ordnance Survey (OS) map (ODPM, 2004). A change would thus be documented even if ‘there [was] no change in the appropriate land use category, but new features [were] added, such as a house being demolished and one or more built in its place’ (ODPM, 2004, p. 2). This approach means that a number of changes were recorded, even if there was no change in the use of land. Such changes are shown in the LUCS 1984/12 (ONS, 2017a) dataset as a change from and to the same land use. Of the sixty-three changes listed in the LUCS 1984/12 dataset that took place in the NQ, twenty-one were of this kind. Removing these types of change leaves a total of forty-two changes, each of which regard shifts in the use of land from one category to a different category over the twenty-eight year period.

Table 1 shows the subsection of forty-two land use changes that occurred in the NQ between 1984 and 2012, excluding the twenty-one instances of change from and to the same land use category. All of the forty-two changes from and to different land use categories occurred on ‘Previously developed land’ and involved a switching between a combination of nine different categories: ‘Residential’, ‘Highways and road transport’, ‘Utilities’, ‘Industry’, ‘Offices’, ‘Retailing, ‘Leisure and recreational buildings’, ‘Vacant land previously developed’ and ‘Outdoor recreation’.

Chart 2 and Chart 3 also concern the forty-two changes that occurred between 1984 and 2012 in the NQ. Chart 2 shows the timing of changes *from* certain land use categories. Chart 3 highlights when changes were made *to* a certain land use category. The graphs thus provide detail regarding the texture of the NQ’s change over time and in so doing complement the data represented in Table 1.

		TO LAND USE																								
	Land Use Description:	Residential	Institutional and communal accommodation	Highways and road transport	Transport (other)	Utilities	Industry	Offices	Retailing	Storage and warehousing	Community buildings	Leisure and recreational buildings	Vacant land previously developed	Derelict land	Minerals	Landfill waste disposal	Defence	Agricultural land	Agricultural buildings	Forestry and woodland	Rough grassland and bracken	Natural and semi-natural land	Water	Outdoor recreation	Urban land not previously developed	Total:
FROM LAND USE	Residential	X											2													2
	Institutional and communal accommodation		X																							0
	Highways and road transport			X			1	1	1																	3
	Transport (other)				X																					0
	Utilities					X																				0
	Industry						X		1				1													2
	Offices	4						X																		4
	Retailing	5		2			1	1	X			1	7													17
	Storage and warehousing	2								X			2													4
	Community buildings										X	1														1
	Leisure and recreational buildings											X														0
	Vacant land previously developed	5				1			2				X											1		9
	Derelict land													X												0
	Minerals														X											0
	Landfill waste disposal															X										0
	Defence																X									0
	Agricultural land																	X								0
	Agricultural buildings																		X							0
	Forestry and woodland																			X						0
	Rough grassland and bracken																				X					0
	Natural and semi-natural land																					X				0
	Water																						X			0
	Outdoor recreation																							X		0
	Urban land not previously developed																								X	0
	Total:	16	0	2	0	1	2	2	4	0	0	2	12	0	0	0	0	0	0	0	0	0	0	1	0	42

Table 1: Land use changes, between 1984 and 2012, in the NQ

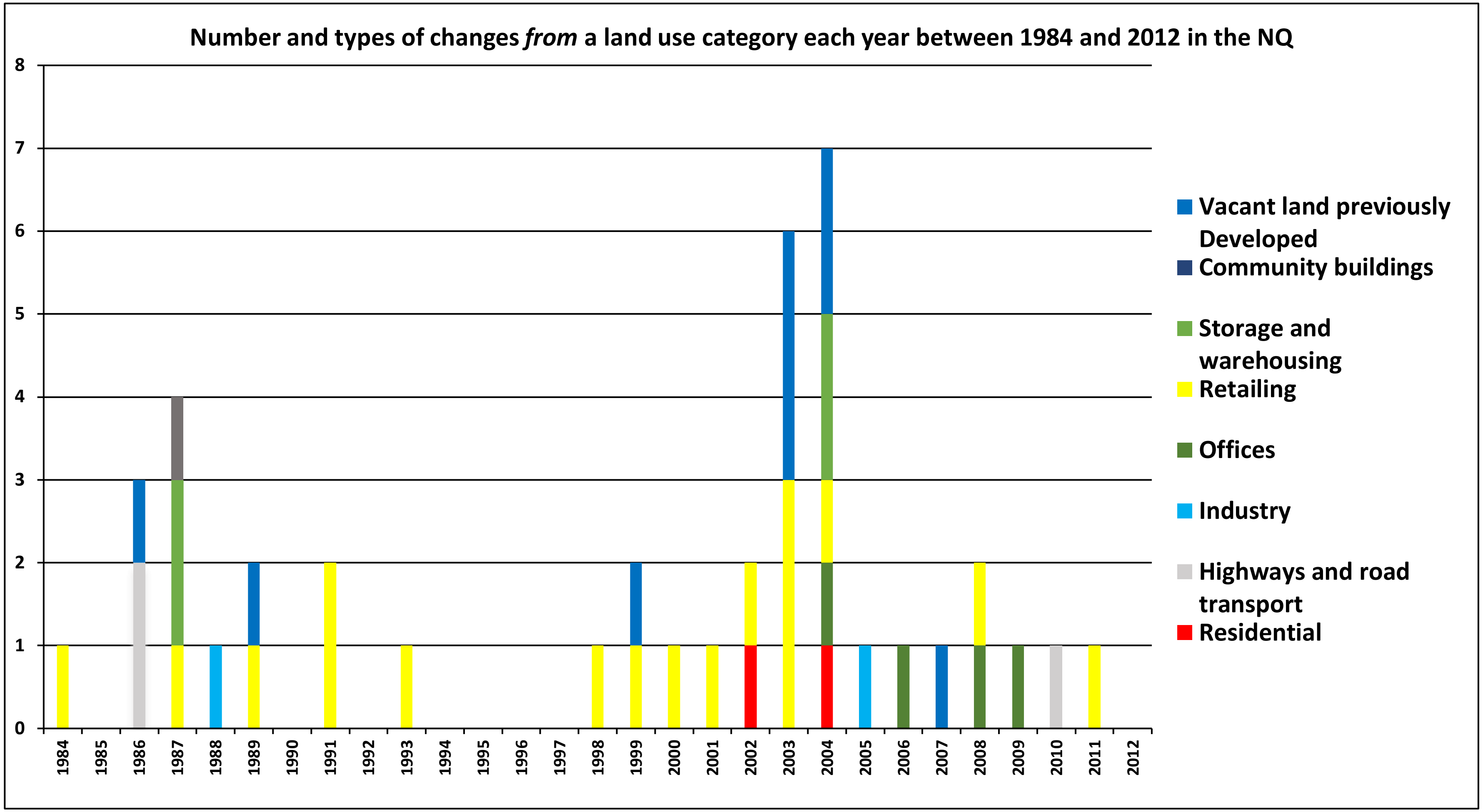

Chart 2: Number and types of changes *from* a land use each year between 1984 and 2012 in the NQ (ONS, 2017a)

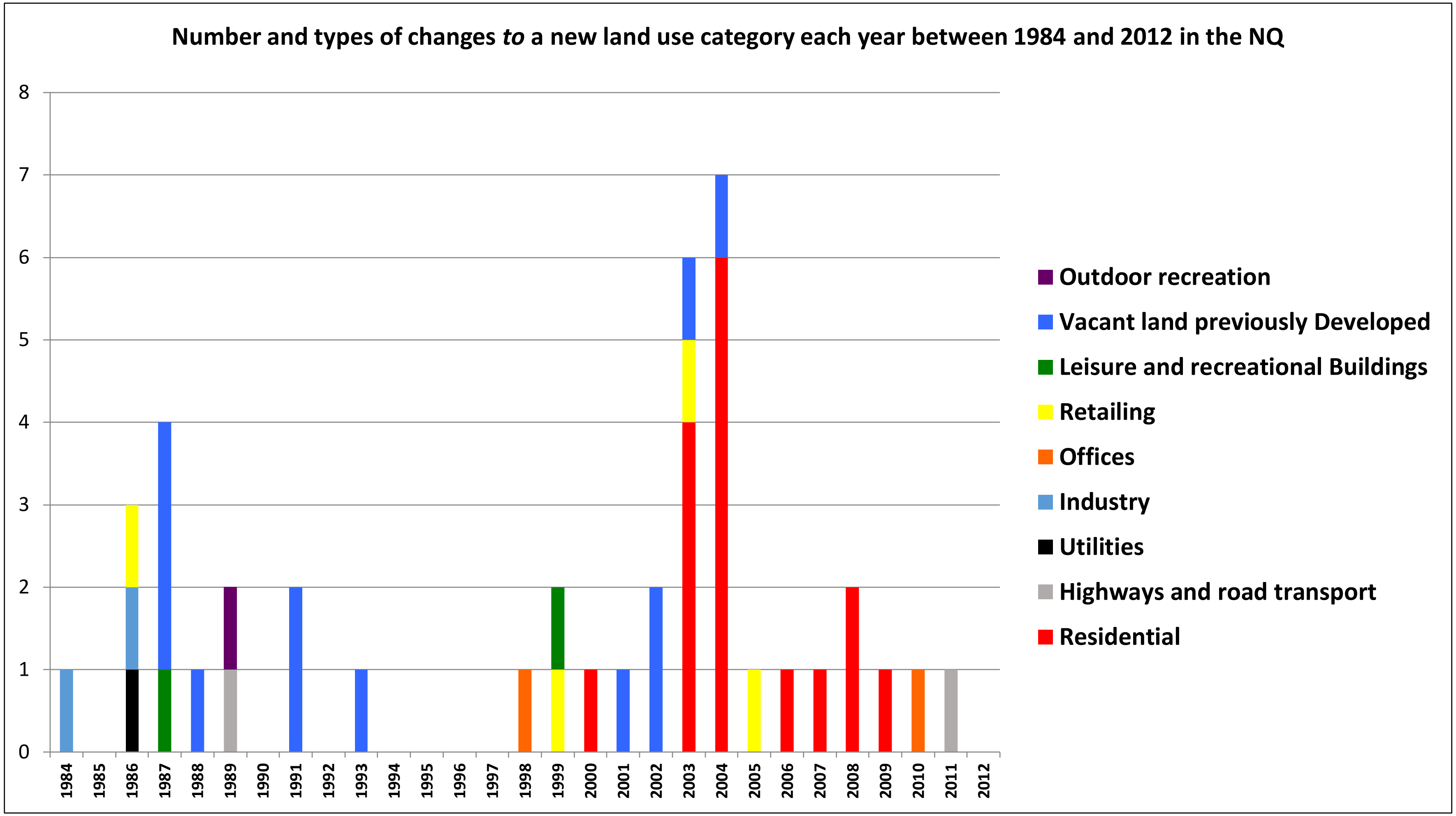

Chart 3: Number and types of changes *to* a new land use each year between 1984 and 2012 in the NQ (ONS, 2017a)

A marked number of the forty-two land use changes in the NQ, between 1984 and 2012, were shifts to ‘Residential’. All changes to ‘Residential’ occurred over a concentrated nine-year period between 2000 and 2009 (Chart 3). In total, sixteen of the forty-two changes recorded were to ‘Residential’. These included: four changes from ‘Offices’ to ‘Residential’, five from ‘Retailing’ to ‘Residential’, two from ‘Storage and warehousing’ to ‘Residential’ and five from ‘Vacant land previously developed’ to ‘Residential’. This composition emphasises how land, previously used for various purposes in the NQ, was swept up in a broader trend of residentialisation between 2000 and 2009.

Changes to ‘Residential’ land use, documented in the LUCS 1984/12 (ONS, 2017a) dataset, also contain detail regarding how many new dwellings were built as a consequence of each change. In total, 757 residential units were built in the NQ between 2000 and 2009. The number of units built each year is shown in Table 2 and Chart 4.

Year:	**Number of residential units built in the NQ between 2000 and 2009:**
2000	95
2003	234
2004	123
2006	84
2007	6
2008	124
2009	91
Total:	**757**

Table 2: Annual number of new residential units built in the NQ between 2000 and 2009 (ONS, 2017a)

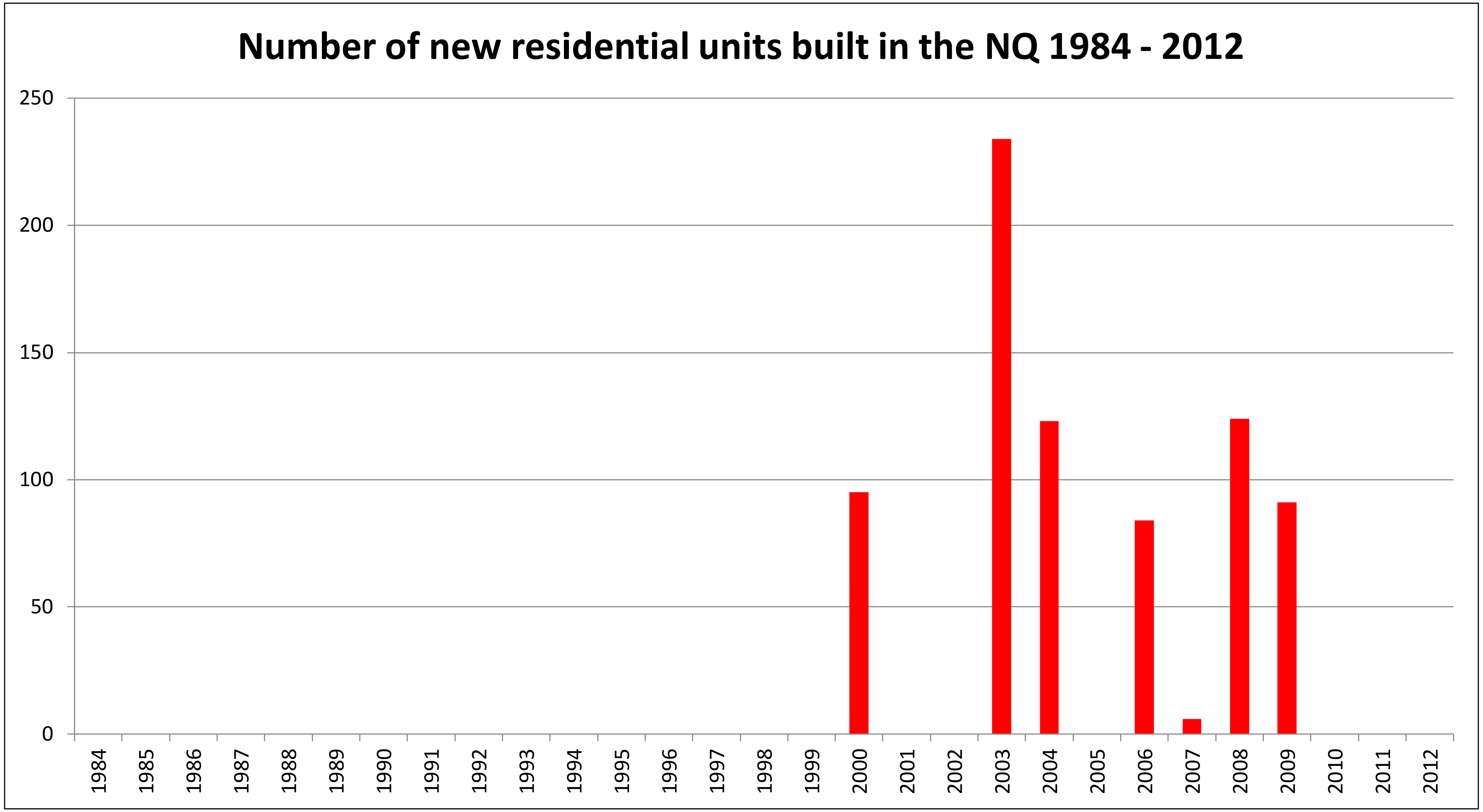

Chart 4: The number of new residential units built in the NQ between 1984 and 2012 (ONS, 2017a)

Another marked shift in the NQ's land use, between 1984 and 2012, concerned changes to 'Vacant land previously developed'. In total, twelve changes to 'Vacant land previously developed' occurred over the twenty-eight year period. As Chart 3 shows, changes to this category specifically took place between 1987 and 2004, with no changes to this category listed from 2005 onwards. The twelve changes to 'Vacant land previously developed' included: seven from 'Retailing', two from 'Residential', two from 'Storage and warehousing' and one from 'Industry'. The 'Vacant land previously developed' category regards:

> Land that was previously developed and is now vacant which could be developed without further demolition or treatment. For example, cleared sites with no fixed structures or building foundations. Includes cleared sites used as temporary car parks or playgrounds, provided no work has been done to facilitate their temporary use and there are no permanent fixtures or structures. (ODPM, 2005, p. 8)

This category is thus fairly ambiguous. It is also of note that although there were twelve changes to 'Vacant land previously developed', between 1984 and 2012, there were also nine changes from this category to another. These included the five noted to 'Residential', one to 'Utilities', two to 'Retailing' and one to 'Outdoor recreation'. These changes occurred specifically between 1986 and 2007, a period similar to the timing of changes to 'Vacant land previously developed'. A toing and froing, from and to land categorised as 'Vacant land previously developed', thus occurred in the NQ between 1984 and 2012.

As noted, of the twelve changes to 'Vacant land previously developed', which unfolded between 1984 and 2012, seven were from 'Retailing'. The category 'Retailing' concerns 'shops, garages, public houses, restaurants, post offices etc.' (ODPM, 2005, p. 7). This trend was part of a larger transition away from 'Retailing' which occurred quite evenly, in terms of timing, across the NQ between 1984 and 2012 (see Chart 2). Specifically, seventeen of the total forty-two changes documented between 1984 and 2012 concerned shifts from

‘Retailing’ to other forms of land use. These included: seven changes from ‘Retailing’ to ‘Vacant land previously developed’, five changes from ‘Retailing’ to ‘Residential’, two from ‘Retailing’ to ‘Highways and road transport’, one from ‘Retailing’ to ‘Industry’, one from ‘Retailing’ to ‘Offices’ and one from ‘Retailing’ to ‘Leisure and recreational buildings’. This shift away from ‘Retailing’ contrasts sharply with the relatively low number of four changes to ‘Retailing’ recorded between 1984 and 2012. As Chart 3 shows, of the four changes to ‘Retailing’, three occurred between 1999 and 2006, the other took place in 1986.

The broader shift away from ‘Retailing’ is counterintuitive to what may be expected, given the NQ’s well-documented emergence as Manchester’s cultural quarter over the past three decades (Wansborough and Mageean, 2000; Guy et al., 2002; Montgomery, 2005; McCarthy, 2006). The marked number of changes away from ‘Retailing’ may also be interpreted as a signal of the more tentative anchoring of practices that this category is taken to represent in this thesis. ‘Retailing’, in comparison with, for example, ‘Residential’ land use, appears to be less stable and more tumultuous. This reading is supported by the limited number of changes away from ‘Residential’ land use, of which only two occurred in the NQ between 1984 and 2012. These two instances of change away from ‘Residential’ land use involved, in total, the demolition of three dwellings.

In summary, between 1984 and 2012 there was a churn within the use of developed land in the NQ. This churning involved nine different land use categories and picked up pace between 1998 and 2012, with two-thirds of the forty-two changes recorded occurring in this fourteen-year period (see Chart 2 and Chart 3). Additionally, two trends also stand out in the LUCS 1984/12 dataset (ONS, 2017b). Firstly, a marked shift to ‘Residential’ land use which occurred in the area between 2000 and 2009. Secondly, a somewhat unexpected and broader move away from ‘Retailing’, which largely took place evenly over the twenty-eight year period discussed.

Land use change in the Northern Quarter between 2013 and 2014

In contrast to the data collected between 1984 and 2012, the dataset concerning 2013/14 does not contain changes from and to the same land use (ONS, 2017b). This means that I did not have to remove changes to and from the same land use category from the LUCS 2013/14 dataset, as I did from the 1984/12 dataset. Additionally, the mobilisation of a 'more detailed' means of tracking land use change is reflected in the number of changes listed in the 2013/14 dataset (DCLG, 2015, p. 11). In total, forty-nine changes were documented. This bears stark contrast with the sixty-three changes listed between 1984 and 2012.

Table 3 details all of the forty-nine changes that occurred in the NQ between 2013 and 2014. All of the changes took place on 'Previously developed land'. Three types of change make up thirty-eight of the forty-nine changes listed. These include twenty-two changes to 'Retail', ten to 'Residential' and six to 'Offices'. The remaining eleven changes included the following: two to 'Highways and roads', one to 'Industry', three to 'Community buildings', one to 'Undeveloped land', one to 'Minerals and mining', one to 'Agricultural building' and two to 'Communal accommodation'.

TO LAND USE

FROM LAND USE

Land Use Description:	Residential	Highways and roads	Transport	Utilities	Industry	Offices	Retail	Storage and warehousing	Community buildings	Vacant land	Undeveloped land	Minerals and mining	Landfill and waste disposal	Defence	Agricultural land	Agricultural buildings	Forestry/Woodland	Natural land	Water	Outdoor recreation	Leisure (indoor)	Rough grassland	Communal accommodation	Residential gardens	Unidentified building	Unidentified general manmade surface (not roadside)	Unidentified structure	Unknown surface type with no classification	Total:
Residential	X						2																						2
Highways and roads		X																											0
Transport			X																										0
Utilities				X																									0
Industry					X		3																						3
Offices						X	9																						9
Retail	5	1			1	4	X		3							1							2						17
Storage and warehousing	1							X																					1
Community buildings						1	4		X																				5
Vacant land										X	1	1																	2
Undeveloped land											X																		0
Minerals and mining		1										X																	1
Landfill and waste disposal													X																0
Defence														X															0
Agricultural land															X														0
Agricultural buildings	4						1									X													5
Forestry/Woodland																	X												0
Natural land																		X											0
Water																			X										0
Outdoor recreation																				X									0
Leisure (indoor)						1	1														X								2
Rough grassland																						X							0
Communal accommodation							2																X						2
Residential gardens																								X					0
Unidentified building																									X				0
Unidentified general manmade surface (not roadside)																										X			0
Unidentified structure																											X		0
Unknown surface type with no classification																												X	0
Total:	10	2	0	0	1	6	22	0	3	0	1	1	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	49

Table 3: Land use changes, between 2013 and 2014, in the NQ

The twenty-two changes to ‘Retail’, as shown in Table 3, involved nine changes from ‘Offices’, four changes from ‘Community buildings’, three changes from ‘Industry’, two changes from ‘Communal accommodation’, two changes from ‘Residential’, one change from ‘Agricultural land’ and one change from ‘Leisure (indoor)’. The six changes to ‘Offices’ involved four changes from ‘Retail’, one change from ‘Leisure (indoor)’ and one change from ‘Community buildings’. There was thus a marked movement in and between the categories of ‘Offices’ and ‘Retail’ between 2013 and 2014, with thirteen of the forty-nine changes listed involving shifts between these categories.

As noted, ten changes to ‘Residential’ land use were recorded in the NQ between 2013 and 2014. The ten changes to ‘Residential’ involved five from ‘Retail’, one from ‘Storage and warehousing’ and four from ‘Agricultural buildings’. During the year 2013/14, there were also only two changes away from ‘Residential’ land use, both of which involved shifts to ‘Retail’.

In the LUCS 2013/14 dataset, the category ‘Residential’ regards ‘areas, including all dwellings, gardens and outbuildings, but excluding all access roads, pavements, paths and verges and any other surrounding infrastructure’ (DCLG, 2015, p. 18). Thus, changes marked under ‘Residential’ do not necessarily reflect the addition of new residential units. To gain an understanding of how many of the changes to ‘Residential’ documented in the LUCS 2013/14 dataset involved the creation of new residential dwellings, I worked with the ONS (2017c) *Residential creations 2013 - 2014 dataset*. This dataset shows that three of the ten changes to ‘Residential’ involved the delivery of new residential units in the area, resulting in the creation of eighty-four new dwellings (ONS, 2017c).

The 2013 to 2014 LUCS dataset thus shows a shifting to and from the land use categories of ‘Retail’ and ‘Offices’, and a marked shift to ‘Residential’ land use in the area. The LUCS 2013/14 dataset in turn reflects a similar trend toward residential land use, which is also captured in the LUCS 1984/12 dataset, and has unfolded in the NQ since the turn of the millennium.

Two trends of land use change in the Northern Quarter between 1984 and 2014

Two broader trends of change have been outlined in this chapter. Firstly, a marked move to residential land use, involving the development of 841 new units between 2000 and 2014. The LUCS datasets, in combination, thus capture a pronounced shift to residential land use in the NQ which occurred specifically between 2000 and 2014.

The area's residentialisation signals the anchoring of an electricity-demanding practice bundle in the area over time. This is because new homes equate with new demands, with residential units tightly packed on top of each other and side by side in the centre of the city. The electricity demand associated with homes in the NQ is particularly acute as it is estimated that at least 84% of properties in the area are off the gas grid and dependent on electricity (Non-Gas Map, 2018). The residential dependency on electricity in the NQ is further captured in Lower Level Super Output Area (LLSOA) data, previously collated by the Department for Energy and Climate Change (DECC) and now handled by the Department for Business, Energy & Industrial Strategy (BEIS) (BEIS, 2019c). As noted, 'LLSOAs are part of a geographical hierarchy… [which have] a minimum population of 1,000 equating to around 400 households' (DECC, 2011, p. 1). LLSOAs support different forms of comparative work concerning geographic areas containing roughly the same population (DECC, 2011). The LSSOA data concerning domestic electricity consumption in the NQ shows that average per-consumer domestic electricity consumption, in the four LLSOAs which cover the NQ, is higher than the average recorded across the Manchester local authority region. In 2012, for example, the average per consumer consumption of electricity in domestic dwellings in the NQ was 73% higher than the average recorded across the whole Manchester local authority region (DECC, 2017). Similar differences were recorded in 2013 (59%) and 2014 (62%) (DECC, 2017). Accordingly, the residentialisation of the

NQ largely sees the creation of an electricity-depended residential geography of demand.

Secondly, my analysis of the LUCS datasets also point to a churning of land uses, particularly in and between the categories of ‘Retailing’/‘Retail’, ‘Offices’ and ‘Vacant land previously developed’. As Chart 2 shows, this churning largely unfolded after 1998. Combined with the marked shift to residential land use between 2000 and 2014, the timing of changes in and between the categories of ‘Retailing’/‘Retail’, ‘Offices’ and ‘Vacant land previously developed’ emphasise a spike in the area’s change between 1998 and 2014. This churning and spike in the area’s land use change can also be interpreted as signalling a changing geography of electricity demand, with the circulation and movement in and out of the area of bundles of electricity-demanding practices spiking between 1998 and 2014.

New questions

A series of questions emerge as consequence of the land use changes and trends outlined in this chapter:

- What informed the NQ’s land use change and thus the spatial reordering of electricity-demanding bundles of practices in the area between 1984 and 2014?

- What shaped the NQ’s residentialisation after the turn of the millennium?

- How did the NQ’s residentialisation since the turn of the millennium and an overall spike in land use change between 1998 and 2014 affect and depend on the management and organisation of the electricity system?

Summary and connections with coming chapters

In this chapter, I have demonstrated one means of tackling the challenge of 'seeing' the spatial constitution of electricity demand in and at the scale of the city. This has been achieved through a study of the NQ's land use change between 1984 and 2014, and using land use categories as proxies for practice bundles. By employing this method, I have foregrounded a churning of commercial land uses, an overall spike in land use change between 1998 and 2014, and a pronounced shift to residential land use since the turn of the millennium. Having detailed these changes, I raised three new questions. These questions are taken up in different ways in the following chapters.

In the next chapter, I consider what affected and informed the NQ's land use change and Central Manchester's broader development since 1984. My analysis involves making a series of connections between intersecting 'global-local' practices and linked policies, trends and events, which I suggest, in combination, contributed to shaping Central Manchester's changing form and function and the constitution of electricity-demand in the centre of the city. This analysis is inspired by and represents a specification of Massey's (1991, 2005) conceptualisation of space as an outcome of 'global-local' trajectories of interlinked practices. By conceptualising and studying the 'global-local' dimensions of the city centre's changing form and function, an equally 'global-local' depiction of the constitution of electricity demand is provided. This depiction suggests that the constitution of electricity demand in the city is little to do with the city itself.

Chapter five, by contrast, concerns the third question listed above. Specifically, I explore the connections between the changing form and function of the NQ, the broader city centre and the 2009 development of the Central Manchester 33 kV Primary Substation. This network-oriented account involves mobilising Bijker's (1995) conceptualisation of 'technological frames' as an analytical tool and means of ordering interview material and secondary sources. My analysis marks a move away from starting with the spatial ordering of practices in order to track and work through the spatial constitution of demand in the city. By instead starting with an instance of infrastructural extension, I articulate an account of how shorter and longer-term expectations, concerning the changing form and function of the city and the constitution of electricity demand, depend on and affect the situated material organisation of the network.

The last empirical chapter again starts with the electricity network but concerns its wider organisation. By starting with the wider organisation of the electricity system, I acknowledge that the NQ and Central Manchester depend on a geographically vast socio-technical network. To understand the connections between the city's changing form and function and the organisation of the electricity system, I analyse different organisational representations of the system and mark out and describe three 'professional worldviews' (Ellis, 1996). Each of the views I articulate emphasises a very different set of dynamics regarding the constitution of the network and how this relates to the spatial ordering of electricity-demanding practices in and beyond the city.

Chapter four: (Not)made in Manchester

Introduction

In this chapter, I 'zoom out' of the Northern Quarter (NQ) and consider the wider context within which the area's land use change and Central Manchester's broader development took shape since 1984. For Nicolini (2009), 'zooming out' represents a shifting of scales, as a means of tracing out broader connections held in and between different practices. My mobilisation of zooming out acknowledges a shift away from focusing in on the ordering of practice bundles in the NQ and a move toward considering the co-evolution of policies, trends and events that can be linked with Central Manchester's contemporary development, land use change, and a reordering of electricity-demanding practices in the city centre.

By zooming out and focusing on the city centre's development in reference to a wider context, I am able to make a series of connections between changes in the residential and commercial mix of the city centre and the broader and longer-term international liberalisation of planning which began in the 1980s and continues to take shape through international, national and local plans, strategies and guidelines. Placing Central Manchester in a wider international context of city centre residential development, I establish another set of connections, this time between the introduction of the Buy-to-let (BTL) mortgage in 1996, the mobilisation and effects of a 'liveable' cities movement, and related flows of investment and people into the city for work and higher education (HE) opportunities. Drawing these elements together and focusing on their layering over time, in combination with the longer-term liberalisation of planning, I establish a set of relationships and points of intersection which I connect with the contemporary residentialisation of city centres across the UK, including Manchester. Although underway in the 1990s, city centre residentialisation across the UK accelerated after the turn of the millennium

(Tallon and Bromley, 2004; Allen, 2007; Rae, 2013; Tallon, 2013). I suggest that this acceleration is a product of intersecting and layering trends.

Alongside the longer-term layering of a liberalised approach to planning and flows of people and investment, which I connect with city centre residentialisation, I also focus on the effects of two international events – the IRA bomb in 1996 and the 2002 Commonwealth Games - on Central Manchester's land use change and development since 1984. I suggest that although these two international events were not made in Manchester, they represent punctuated moments in the city's history, which acted as stimulants of urban regeneration and stand out against the continuity of ongoing and broader forms of change and development.

The connections drawn in this chapter reflect engagement with Massey's (1991, p. 28) spatial thesis and argument that 'a place… [is] constructed out of a particular constellation of social relations, meetings and weavings together at a particular locus'. However, while Massey (1991, 2005) focuses explicitly on the constant and ongoing constitution of space, I show the uneven spatial and temporal organisation of electricity-demanding practices in Central Manchester over time. In this regard, my specification of Massey's (1991, 2005) ideas provides a spatially-sensitive account of the organisation of electricity demand in Central Manchester, which goes beyond highlighting constant and unending change, pointing instead to periods of relative continuity, juxtaposed by moments of accelerated development.

By focusing on the specificity of Central Manchester's change over time, in reference to a wider national and international historical context, I specifically describe how the ongoing spatial formation of electricity demand is connected with a series of trends and linked flows of people, investment and ideas, which intersect and knot together, informing patterns of land use change and urban development. These knots are often not made in Manchester, yet, nor are they unstructured or perpetual expressions of global flows. Instead, with infrastructural development and with land use, there are identifiable thresholds and strongly materialised dimensions of different intersecting policies, trends and events.

'Lifting the burden': The liberalisation of planning

In this section, I focus on the longer-term national and local liberalisation of planning, within which the land use changes discussed in the previous chapter took shape. My analysis draws on expert interviews with planning and regeneration professionals and an examination of the contents and links between nineteen local and national planning policies, strategies, acts and reports published between 1945 and 2012 (Appendix 2). My analysis thus covers a prolonged period and involves moving between documents, which although related, were published years apart. As I explain, initial moves to liberalise planning practices were part of a wider 'lifting of the burden' of regulation, synonymous with the politics of Margaret Thatcher's Conservative government during the 1980s (Rowan-Robinson and Lloyd, 1986; Thornley, 1986). The liberalisation of planning specifically aimed at 'lifting the burden' of legislation perceived as prohibitive to commercial development (Rowan-Robinson and Lloyd, 1986; Harries and Sawyer, 2014). Although the roots of the liberalisation of planning date back to the 1980s, this process has continued to unfold and take shape over time and at a global scale (see for example Organisation for Economic Co-operation and Development (OECD) (2017) policy analysis and land use recommendations).

In what follows, I firstly consider the history of the national reduction of red tape in the UK, which is part of a broader global shift toward a flexible approach to planning. Subsequently, I describe how the liberalisation of planning unfolded in Manchester and how this relates to the city centre's development and change since 1984.

The national liberalisation of planning

My review of planning strategies and spatial frameworks reveals a transition, which began in the 1980s, away from the rules laid out in the *Town and Country Planning Act 1947* and a shift toward a more liberalised approach to land use planning in the UK. *The Town and Country Planning Act 1947* is a seminal document in the history of land use planning in the UK (Rowan-Robinson and Lloyd, 1986). The Act established the requirement for developers to secure planning permission before land could be developed: no longer did land ownership imply a right to develop a piece of land or a building (Rowan-Robinson and Lloyd, 1986; Rowan-Robinson et al., 1987). Instead, the right to develop would involve gaining planning permission from a designated local planning authority (Rowan-Robinson and Lloyd, 1986). And, gaining planning permission depended largely on complying with the detailed local plans, planning authorities were expected to develop (Booth, 2003). These local plans set out the intended uses of particular areas and thus acted as a guide for development (The Manchester City Council (MCC, 1967) *Manchester City Centre Map* is a typical example of such a plan). The 1947 Labour government set aside £300 million to support the delivery of local authority plans (Kahn-Freund, 1948, p. 73). The 1947 Act thus represented the constitution of a national planning system, which aimed at organising and providing ‘universal control’ over land use change (Booth, 2003, p. 3).

Over time, however, the tenets laid out in the *Town and Country Planning Act 1947* came to be seen as a burden to development (Rowan-Robinson and Lloyd, 1986; Harries and Sawyer, 2014). Fitting in with a broader programme of ‘lifting of the burden’ of regulation, a loosening and reorganisation of planning legislation accordingly took shape under the guidance of Margaret Thatcher’s government throughout the 1980s and early 1990s. As Harries and Sawyer (2014, p. 10) note:

> The Government under Margaret Thatcher placed particular importance on supporting free markets and open competition… It argued that the amount of regulation was acting as a brake on enterprise… [The Government] identified around 80 regulatory measures, including planning, tax and social security, employment protection, and trade and industry, which it said were a major drain on businesses – particularly small businesses – both in terms of direct costs and management overheads.

The Conservative government's ardent belief in deregulation is further portrayed in the former Prime Minister's own words. As she explained:

> … [The] basic fact remains: every regulation represents a restriction of liberty; every regulation has a cost. That is why, like marriage (in the Prayer Book's words), regulation should not 'be enterprised, nor taken in hand, unadvisedly, lightly, or wantonly'. (Margaret Thatcher, 2013, cited in Harries and Sawyer, 2014, p. 10)

Building on this philosophy, the government published a White Paper entitled *Lifting the Burden* (Trade and Industry, 1985), which was indicative of the planning approach the government wanted to instil.

The 1985 White Paper underlined the expectation that local authorities would support development, as opposed to inhibiting possibilities for commercial gain (Robinson and Lloyd, 1986). The guidance presented in the White Paper was further supported by regulation, which removed the requirements of local planning permission in certain areas and in relation to specific developments (Robinson and Lloyd, 1986). Planning permission was, instead, to be granted prima facie in designated areas, provided plans were in 'accord with proposals… previously approved by the Secretary of State' (Robinson and Lloyd, 1986, pp. 56 - 57). This legislation was supported by changes set out in the earlier published *Local Government, Planning and Land Act (1980)*, which outlined specific planning rules regarding enterprise zones – areas free from 'normal' planning regulations (Robinson and Lloyd, 1986).

The burden of legislation was lifted further by the *Town and Country Planning Act 1990*, which allowed Unitary Development Corporations, public-private hybrids, to take charge of planning within designated zones (see: section 7 of *The Town and Country Planning Act 1990*). The liberalisation of planning thus took shape through political work, at a national scale, which, as I explain below, shaped local city plans and their associated aims and objectives.

The liberalisation of planning in Manchester

The effects of a national 'lifting of the burden' of regulation and a shift toward a liberalised approach to planning resonated in the work of Manchester City Council (MCC) and other agencies involved in the city centre's planning, development and regeneration. As John, an MCC employee with over forty-years' experience working in urban regeneration explained, with regards to the effects of the national agenda of liberalisation that began in the 1980s: 'the national context that people were operating in [was] important in determining the dynamics of the game' (John, MCC employee, and planning and regeneration professional). The game, he further explained, concerned the expectations of the National Government regarding the cutting of 'red tape', in order to open up the city to investment and commercial development.

Dan, an MCC employee and planning practitioner, with forty-two years' experience working for the local authority, echoed John's sentiment. He discussed and reflected on how MCC recognised the importance of playing the game, conforming with the rules of the day and meeting the expectations and political logic of Margaret Thatcher's government:

> We [(MCC)] knew we had to do it in a different way… So, what we decided to do… was abide by the rules and look at how we could secure

> government money and investment in the city rather than trying to do our own thing and not getting any government money and investment in the city…. The only way to do it was to play by the rules, not say how unfair the rules were. (Dan, MCC employee, and planning and regeneration professional)

Dan explained that this ‘different way’ was captured in the *Manchester City Centre Local Plan* (MCC, 1984), a publication that marked a move away from what traditionally constituted a planning document, as a consequence of not adhering to the tradition of delineating strict zonal plans and related policies. As Dan observed:

> [The] plan… broke the mould for plans because it didn’t zone things, it didn’t allocate things. It talked about an aspirational vision for the city, about the kind of city we wanted to create. And, it talked about things like mixed-used and housing and that kind of stuff, and it didn’t have fixed views on ‘you must do this here’ and ‘must do that there’… it was so different as a plan, that when we took it to the government office at the time, because you needed approval for a plan, they said: “that’s not a plan, you cannot use that”. And we said: “ok, we’ll call it an informal plan, and we won’t have it as formal planning policy”. And they said: “if you put a plan on the back, we’ll call it one”. And so, we had this local plan. (Dan, MCC employee, and planning and regeneration professional)

Dan thus pointed to a specific transition in the planning approach mobilised by MCC, distilled in the form of the *Manchester City Centre Local Plan* (MCC, 1984). He also suggested that there were simultaneously different ideas of what constituted a plan. The *Manchester City Centre Local Plan* (MCC, 1984), whilst not conforming with longer held expectations of what constituted a planning document, simultaneously represented a shift that fitted with the broader national politics of the time and ultimately formed a proposal that was adopted with the addition of a traditional ‘plan’, which was quite literally backgrounded as a consequence of being printed on the back of the *Manchester City Centre Local Plan* (MCC, 1984).

The shift in approach and liberal-turn represented in the *Manchester City Centre Local Plan* (MCC, 1984) was realised, as Dan explained, through the support for mixed-use development across the city centre, which would see residential developments bundled together with commercial floorspaces and offices. Gone were more prescriptive area-specific visions, set out in previous plans and strategies, such as the *Manchester City Centre Map* which outlined 'five comprehensive planning proposals… [for] areas amounting to 200 acres and representing most of… the central area' (MCC, 1967, p. 55) (see Figure 8). These area-specific plans were orientated around particular functions, including, for example, higher education, civic duties, commercial shopping and leisure activities (MCC, 1967, p. 55). They further helped to steer and foster the production of a particular material and electricity-consuming geography, which largely saw a geographic separation of work, leisure and residential demand.

Figure 8: MCC 1967 comprehensive planning proposals map for the city centre (MCC, 1967, p. 55)

In place of plans organised around prescriptive zoning, like those in the *Manchester City Centre Map* (MCC, 1967), came a liberal and homogeneous neighbourhood approach to planning. This approach is seen in the *Manchester City Centre Local Plan* (MCC, 1984, p. 39), and the plan's central aim that 'mixed uses… [should] be encouraged throughout the plan area'. This aim was so different to previous aims, outlined in more traditional plans, that John suggested the 1984 *Manchester City Centre Local Plan* 'was not really a plan at all' (John, MCC employee, and planning and regeneration professional). It was, instead, a declaration that the council would welcome most forms of development in and across the city centre. This declaration not only signalled the constitution of a new vision of the city but also a related geography of electricity demand, premised on a bundling together of land uses. As a consequence of constituting this new vision of the city, the *Manchester City Centre Local Plan* (MCC, 1984) was, on the one hand, 'ahead of its time' (Williams, 2002, p. 160), and on the other, complementary to the broader expectations and agenda of the national government of the period.

Dan explained that the *Manchester City Centre Local Plan* (MCC, 1984) 'was still being used in the early 2000s' (Dan, MCC employee, and planning and regeneration professional). This remark suggested that the strategy had longevity and that its principles had stood the test of time, representing useful, productive and influential development guidelines over a prolonged period.

Reinforcing Dan's suggestion, I found, as a consequence of my review of MCC plans and strategies, that seventeen general policies outlined in the *Manchester City Centre Local Plan* (MCC, 1984) were adopted without alteration by the Central Manchester Development Corporation in 1988 (see: Central Manchester Development Corporation (1990)). The Central Manchester Development Corporation was a public-private Urban Development Corporation which operated between 1988 and 1996 (Deas et al., 2000). The Corporation oversaw an expenditure of £100.6 million and focused on transforming a major portion of the city centre (Deas et al., 2000) (see Figure 9). Thanks to statutory legislation changes outlined in the *Local Government Planning and Land Act 1980* (UK Public General Acts, 1980), the Central Manchester Development Corporation, like other Urban Development Corporation's in Cardiff, Bristol, Leeds, London and Liverpool, had the legislative power to manage planning and the use of land. Specifically, the Central Manchester Development Corporation oversaw planning and land use across a 187-hectare portion of the city centre (Central Manchester Development Corporation, 1990).

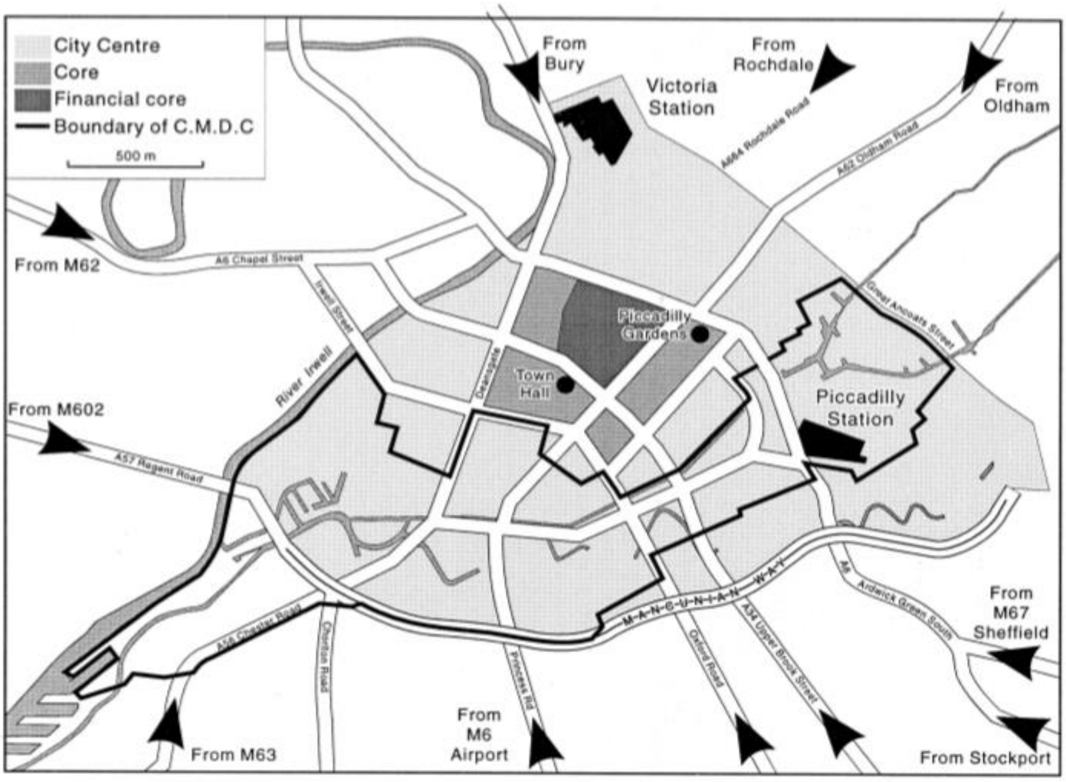

Figure 9: Central Manchester Development Corporation boundaries (Deas et al., 2000, p. 8)

As Deas et al. (2000, p. 10) note, with regards to the Central Manchester Development Corporation's strategy:

> Its formal objectives drew directly from the *1980 Local Government Planning and Land Act*: to bring back into use land and property; to support new developments sympathetic to incumbent buildings; to utilise private finance to underpin (re)development; and to improve the environment.

The Central Manchester Development Corporation thus aimed at implementing a liberalised agenda by fostering public-private partnerships as a means of delivering urban regeneration (Williams, 1996; Deas et al, 1999, 2000). In this regard, the Central Manchester Development Corporation:

> Sought [to] radically… alter the character of the city centre's southern fringe by supporting a series of housing and leisure-based developments

> which… would assist the diversification of the city centre. (Deas et al., 2000, p. 10)

This diversification involved an embrace of mixed-use developments and a movement away from cramming in, for example, 'the city's financial institutions… into a narrow 'square half-mile' financial district, with limited opportunities to develop elsewhere in the city centre' (Deas et al., 2000, p. 10).

The aim of supporting mixed-use development culminated in the delivery of more than 2,500 new or refurbished dwellings in the Central Manchester Development Corporation area and over 100, 000 m2 of office space (Williams, 1996; Deas et al., 2000). The same area had an estimated population of 250 in 1988 (Deas et al., 2000).

The broad vision of Manchester city centre, outlined in the *Manchester City Centre Local Plan* (1984), was thus given life through the direct work of the Central Manchester Development Corporation. Moreover, the Central Manchester Development Corporation helped to produce a new electricity-demanding geography by, for example, specifically facilitating mixed-use and residential development in the centre of the city (Williams, 1996; Deas et al., 2000).

The liberalised approach - outlined in the *Manchester City Centre Local Plan* (MCC, 1984) and seen in the work of the Central Manchester Development Corporation - was further taken up and reproduced in the Urbanistics (1994) *Northern Quarter Regeneration Study*. Within this study, it is noted that the principles laid out in the *Manchester City Centre Local Plan* 'remained robust and useful in guiding the future… of the Northern Quarter' (Urbanistics, 1994, p. 19). It is further stated that the main objectives of the *Manchester City Centre Local Plan* (MCC, 1984), including 'better transport initiatives…, more housing, [and] a desire to get a mix of uses…[,] meant that inappropriate developments (for example, large-scale office developments… with no mixed uses) [were] discouraged' in the NQ between 1984 and 1994 (Urbanistics, 1994, p. 19). The aims of the *Manchester City Centre Local Plan* (MCC, 1984), in terms of steering and guiding land use and the related spatial ordering of electricity-demanding practices, thus appear to have informed and affected the NQ's ongoing development.

Within the city-wide *Unitary Development Plan* (MCC, 1995b), which was required as a part of the alterations made to *The Town and Country Planning Act 1990*, the significance of the *Manchester City Centre Local Plan* (1984) and its flexible principles are again foregrounded. As noted:

> In 1984 the Council adopted the *City Centre Local Plan* as the statutory planning framework for a major part of the Regional Centre… The Council considers that the policies contained within the former City Centre Local Plan continue to provide a useful and relevant planning framework for today's Regional Centre. (MCC, 1995b, p. 92)

In turn, as with the earlier Central Manchester Development Corporation (1990) *Development Strategy for Central Manchester*, the *Unitary Development Plan* (MCC, 1995b) thus marks out a continuing embrace of a liberalised approach to planning in Manchester. The *Unitary Development Plan* (MCC, 1995b) represented an updated and comprehensive planning guide for the city between 1995 and 2012. This remained the key planning document for the city until the publication and adoption of the *Manchester Core Strategy 2012 to 2027* (MCC, 2012).

However, the publication of the *Manchester Core Strategy 2012 to 2027* (MCC, 2012) did not mark a significant move away from the flexible approach to planning adopted and mobilised by MCC in the 1980s and distilled in the *Manchester City Centre Local Plan* (MCC, 1984). As Jane, an MCC planning officer with over fifteen-years' experience explained, in response to a question concerning whether the division of the city centre into discursive quarters - such as the Northern Quarter, China Town, Spinningfields and the Central Business District - affected the Planning Department's contemporary work:

> I wouldn't say that it necessarily has a big impact on how we deal with day-to-day information… because most of the city centre is a mixed-use area. So, when we get applications, you know not everything is acceptable anywhere, but there is a large level of that. (Jane, MCC employee, and planning and regeneration professional)

As Jane further explained, in reference to current planning practice enacted by MCC: 'we don't use any different parameters to judge applications that come in that area [(the NQ)] than we would elsewhere in the city' (Jane, MCC employee, and planning and regeneration professional). Echoing Jane, Dan suggested that 'if you look at Manchester's planning policies now [(2018)], they are flexible, they allow people to develop ideas within an overall city context' – a context that sees a broad and continuing support for mixed-use development across the city centre (Dan, MCC employee, and planning and regeneration professional).

The liberalised approach to planning adopted by MCC in the 1980s, which fitted with a broader national programme of 'lifting the burden' of regulation, associated with the Conservative government's wider agenda, thus remains a key feature of the local authority's approach to land use planning. The effects of the liberal-turn continue to involve the support of mixed-use development across the city centre, a move which originally marked an opening up of the city and a movement away, in a formal sense and to some extent, from the application of stricter zoning techniques. Since the publication of the *Manchester City Centre Local Plan* (MCC, 1984) and through the work of organisations which mobilised the principles outlined in this key document, such as the Central Manchester Development Corporation, Central Manchester has, over time, increasingly become a mixed-use electricity-demanding location.

City centre residentialisation

The embrace and mobilisation of a liberalised approach to planning over the past four decades fit broadly but not neatly with a period of residentialisation experienced in city centres across the UK (Tallon and Bromley, 2004; Bromley et al., 2007; Rae, 2013). In regards Manchester city centre, it is estimated that five-hundred people lived in the area in 1984 (MCC, 1984). By 2015, this number had jumped to 35,600 (Swinney and Carter, 2018). Focusing on Manchester's broader return to population growth, Rae (2013, p. 96) writes that the local authority region's populace breached the 'half million mark for the first time since the 1971 census' in 2011.

In terms of the timing of the city's population growth, like other cities around the UK, Manchester experienced an accelerated period of change after the turn of the millennium. Between 2001 and 2011, the Manchester local authority region experienced a 19% upturn in its population (Swinney and Carter, 2018). This made Manchester the fastest-growing town or city in the UK in terms of population during this period (Rae, 2013). Over the same timeframe, the following increases were witnessed in other cities: Bristol 12.5%; London 12%; Nottingham 14.5%; Birmingham 9.8%; Newcastle 7.9%; Sheffield 7.7%; Liverpool 6.1%; and Leeds 5% (Rae, 2013).

Like other cities around the UK, Manchester's population growth between 2001 and 2011 was also concentrated in the centre of the city (Tallon, 2013). As Rae (2013) notes, two of the top ten fastest-growing Lower Level Super Output Areas (LLSOA) in UK city centre cores, between 2001 and 2011, were in Manchester city centre, with 565.9% growth in one area and 358.3% in the other. Similarly, the population of one ONS derived LLSOA area in the centre of Sheffield rose by 608.2% between 2001 and 2011 (Rae, 2013). Furthermore, the residentialisation of urban space in the centre of English cities follows a broader global phenomenon of urbanisation, with 2007 marking 'the first time in history,

[that] the global urban population exceeded the global rural population' (United Nations, 2014, p. 7).

The growth of the Manchester local authority region's population dovetailed with an increase in residential land use. It is estimated that the total number of dwellings in the Manchester local authority region increased by 28,530, from 185,000 to 213,530, between 2001 and 2011 (Ministry of Housing, Communities & Local Government, 2019). Predictably, given the area's population growth, the city centre has proved a hotspot for residential development since the turn of the millennium (Deloitte, 2018, 2019).

The timing of the acceleration of residential land use change experienced in Manchester city centre and across other UK cities suggests that the liberalisation of planning was only an element and dimension of contemporary urban residentialisation. In turn, questions arise regarding what led to and spurred on the rapid development of land for residential purposes in Central Manchester and other cities across the UK after the turn of the millennium.

Continuing to 'zoom' out, in the coming section I focus on the wider context of accelerated city centre residentialisation across the UK, making a series of connections between the introduction of the Buy-to-let (BTL) mortgage, the emergence of a contemporary 'liveable' cities movement and processes of studentification. I make these connections as a means of helping to explain the acceleration in residential development experienced in the city centre after the turn of the millennium. My analysis helps to explain why the liberalisation of planning, as discussed above, might have enabled but did not of itself produce an increasingly residential electricity-demanding geography in city centres across the UK. The connections I make suggest that Manchester city centre's residential development can be usefully understood to have been informed and spurred on by particular 'global-local' trends of investment and flows of people. Drawing inspiration from Massey's (1991, 2005) conceptualisation of space, I suggest that contemporary city centre residentialisation is usefully interpreted as an outcome of a set of intersections, which take shape over time and culminate in particular moments and periods of residential land use change and the anchoring of residential bundles of electricity-demanding practices in sites, such as Manchester city centre.

Buy-to-let mortgages and investor-led residentialisation

One way to interpret Manchester city centre's residentialisation is in relation to the emergence and growth of the Buy-to-let (BTL) mortgage. The BTL was introduced in the UK in 1996 and built on legislation outlined in the *Housing Act 1988* (UK Public General Acts, 1988). The Act was consistent with the Conservative government's wider liberalisation agenda and specifically aimed at opening up the housing market through the introduction of assured short-term tenancies (AST) for domestic rentals (Leyshon and French, 2009). ASTs mean 'that there is little security for tenants and tenancies are generally short in duration', making it easier for landlords to evict tenants and change the terms of tenancy more often (Clapham et al., 2014, p. 2022). The BTL mortgage also provided favourable lending arrangements for buyers, circumventing previously high premiums for those participating in the private rental market (Leyshon and French, 2009).

The significance and impact of the BTL mortgage is widely acknowledged, with the product understood to have acted as a strong stimulant for investment in property (Sprigings, 2008; Leyshon and French, 2009; Mellish and Rhoden, 2009; Clapham et al., 2014). In the UK, between 1996 and 2007, there were, for example, '1,024,300 outstanding "buy to let" mortgages… with a value of £116 billion' (Council for Mortgage Lenders (CML) 2007 cited in Mellish and Rhoden, 2009, p. 178). Indeed:

> Since Buy-to-let emerged…, it has grown strongly. Lenders have advanced more than 1.7 million Buy-to-let loans since… 1999. Over this time, the private rented sector has seen nothing less than a renaissance

> – doubling in size over the past 12 years, following decades of steady decline. Buy-to-let mortgage balances outstanding recently grew to more than £200 billion – equivalent to the gross domestic product of Hong Kong. (Clarke, 2015)

BTL mortgage loans thus form a major part of the UK housing market. They have further been connected with the growth of residential development across the UK (Leyshon and French, 2009).

The regeneration practitioners with whom I spoke specifically linked the availability and use of BTL mortgages to Manchester city centre's contemporary residentialisation. For Tony, the BTL was a 'big factor' (Tony, MCC employee, and planning and regeneration professional). Tony explained that the 'fantastic returns on capital growth', related to the BTL mortgage, meant that residential development was not only financially viable but a very economically lucrative endeavour (Tony, MCC employee, and planning and regeneration professional).

The economic benefits and draw of participating in the BTL market are particularly evident in the increasing value of property in the city over the past twenty years. Figures collated by Zoopla, a major UK-based property portal, estimate a 239.05% increase in the average price paid for a property in Manchester city centre between 1999 and 2019 (Zoopla, 2019). Such increases, coupled with favourable lending arrangements, have seen Manchester become a BTL investor hotspot since the introduction of the product in 1996 (Allen, 2007; Pickford , 2017; Smith, 2019). Allen (2007, p. 679) found, for example, through interviews with estate agents in Manchester, that in 2007 an estimated '85% - 99% of people buying apartments' in the city centre were investors connected with the use of BTL mortgages.

Manchester city centre's residentialisation can thus be read in relation to the 1996 introduction of the BTL mortgage. Set in the context of a wider and longer-term programme of liberalisation in the UK, which, as outlined, started with

Margaret Thatcher's Conservative government in the 1980s, the introduction of BTL mortgages has acted as a stimulus for residential development, providing particularly favourable lending arrangements and a rationale for investing in private property. In these terms, patterns of investment in residential property, linked with the introduction of mortgage options, such as the BTL, build on and relate to the wider liberalisation of planning discussed in the previous section. While the liberalisation of planning involved opening up the possibility of residential land use across the city centre, which was distilled in publications such as the *Manchester City Centre Local Plan* (MCC, 1984), the BTL mortgage provided favourable lending arrangements that made residentialisation a financially lucrative endeavour (Leyshon and French, 2009). Accordingly, Manchester city centre's accelerated residentialisation can be fruitfully interpreted as an outcome of the layering of policies and favourable lending arrangements, which in combination produce and prompt residential development.

There is, however, more to be said regarding Central Manchester's residentialisation. As it stands, I have only provided an account of the creation of a lucrative mortgage option, with well-established links with residential property investment across the UK (Mellish and Rhoden, 2008; Sprigings, 2008; Leyshon and French, 2009; Clapham et al., 2014; Clarke, 2015). This account misses out how and why people have increasingly come to live in the centre of cities since the turn of the millennium (Rae, 2013; Tallon, 2013; Swinney and Carter, 2018). To understand how city centres across the UK have become residential hotspots, it is also useful to consider the emergence and the effects of a 'liveable' cities agenda and its mobilisation through policy.

The effect of a 'liveable' cities' agenda

For city centres across the UK to become residential investment and electricity-demanding hotspots, there had to be people willing to live in cities and cities had to be made 'liveable' sites. In this regard, the demand for city centre residential development, since the turn of the millennium, dovetails with the emergence of a broader 'liveable' cities discourse and related agenda. In contrast to previous urban design paradigms, such as Howard's (1898) dispersed garden cities or Le Corbusier's (1946) modular rationalism, the contemporary 'liveability' movement has been linked with the separate works of Jacobs (1972) and Mumford (1940, 1961), and their concern for the constitution of living city centre neighbourhoods (Berg, 1999; Stephenson, 1999; Evans, 2002; Mellon, 2009). Drawing on this idea, a growing institutional interest in constituting 'liveability' has taken shape on a global scale, with the production of economically viable, environmentally friendly, safe and secure urban spaces, underpinned by necessary infrastructure and service provision, forming key aspects of urban design discourse (Ley, 1990; Kaal, 2011).

While Kaal (2011) questions whether the global 'liveability' movement represents more than a discursive frame, in a UK context, it is possible to make connections between an interest in constituting urban liveability and an acceleration of city centre residentialisation. The publication of the White Paper *Our Towns and Cities: The Future,* in 2000, marks out a national government interest in making UK city centres liveable spaces (Department of the Environment, Transport the Regions (DETR), 2000). As Rae (2013, p. 94) explains:

> This White Paper addressed issues of neglect, poor management, inadequate public services and lack of investment in English cities… it drew heavily from the recommendations of the earlier Urban Task Force report [*Towards an Urban Renaissance*] (Urban Task Force, 1999) and set out a vision for reviving English cities, under the rubric of the idea that 'how we live our lives is shaped by where we live our lives'. (DETR, 2000, p. 5)

A key commitment outlined in the White Paper concerned the aim of developing '60% of new housing in England… on brownfield land, or through the conversion of existing housing' by 2008 (Rae, 2013, p. 95). As Rae (2013, p. 94) notes:

> In attempting to meet this target, local authorities would necessarily have to draw upon large areas of derelict industrial land and buildings at their centres and people would, in theory, return to the inner city in unprecedented numbers. This was already beginning to happen in 2000, but it was more evolution than revolution at this stage.

A national concern with constituting 'liveable' thus resulted in government policy and targets angled toward constituting city centres as places to live. Again, as with the timing of the introduction of BTL mortgage in 1996, the publication of the Urban Task Force (1999) report - *Towards and Urban Renaissance* - and *The Our Towns and Cities: The Future* (DETR, 2000) publication can be read as connected and productive preambles to the acceleration of residentialisation across UK city centres.

This being said, a national concern with producing 'liveable' cities and the availability of BTL mortgages does not fully explain why people have been drawn, en masse, to live in city centres across the UK. Focusing on the social groups which live in city centres proves useful in this respect.

Residential demand

The growth of UK city centre populations, since the turn of the millennium, has largely involved the migration of two cohorts - young professionals and students - both of which have been linked with the growing demand for assured shorthold tenancies (ASTs) and thus what the Buy-to-let mortgage facilitates (Hoskins and Tallon, 2004; Smith, 2005, 2008; Allen, 2007; Rugg and Rhodes, 2008; McKee et al., 2017). In this regard, the organisation of the housing market in Manchester city centre and the area's demographic composition are typical of other UK cities. Census data shows that within the City Centre Ward, within which much of the NQ lies, 76% of residents were aged between twenty and forty-four in 2011 (MMC, 2018). 49.5% of the City Centre Ward's population was also comprised of residents classified within the 'Full Time Student and not classified' category, a significantly higher proportion than the 20.8% of residents falling within this group living across the whole of the Manchester local authority region in 2011 (MCC, 2018a). 34.1% of the City Centre Ward's total employment was further split between two categories in 2011: 'Higher Managerial and Professional' (17.1%) and 'Lower Managerial and Professional' (17%). The City Centre Ward's population, in 2011, was thus largely comprised of younger professionals and students, which have migrated into the centre of cities across the UK and tend to demand ASTs and what the BTL mortgage supports (Rugg and Rhodes, 2008; McKee et al., 2017).

Such connections are also reflected in the composition of the housing market in the City Centre Ward. While only 30% of properties were privately rented across the Manchester local authority region in 2011, 44.5% were under this form of tenure in the City Centre Ward (MCC, 2018a). Moreover, in contrast to the other thirty-one council wards, which comprise the rest of Manchester local authority region, the City Centre Ward experienced the largest increase in the total number of residents privately renting in the area between 2001 and 2011, with an increase of over 225% during the ten-year period (MCC, 2018a).

The high proportion of students living in UK city centres, including Manchester city centre, suggests that a key aspect of urban residentialisation is related to the organisation of higher education (HE). Conceptualising the connections between urban residential development, the migration of students into city centres and a reordering of HE, scholars have written about processes of 'studentification' (Chatterton, 1999; Tallon and Bromley, 2004; Smith, 2005, 2008; Hubbard, 2008). Studentification, like gentrification, reflects a transition in the demographic composition of a place, with students coming to rent and live in areas previously associated with other social groups (Hubbard, 2008). It is a process also synonymous with the ongoing liberalisation and 'massification' of HE across the UK (Hubbard, 2008, p. 325), which have been linked with Tony Blair's tenure in office and the Labour Party's 1999 manifesto 'commitment to

[a] ten-year target of 50% of 18–30 year-olds entering [HE]’ (Lunt, 2008, p. 745).

In terms of the growth of student numbers, there were 271,000 full-time undergraduate university applicants in the UK in 1994, by 2011 this number had risen to 492,000, representing an 82% increase (House of Commons Library, 2018a). In Manchester specifically, it is estimated that in the academic year 1994/95 there were 80,260 undergraduate and postgraduate students studying in the seven[9] universities in and around Manchester city centre (Higher Education Statistics Agency (HESA), 2018). By contrast, it is estimated that in the academic year 2010/11, 107,540 students were studying in the five[10] universities close to Manchester’s city centre (HESA, 2018). Between 1994/95 and 2010/11, there was thus a 34% increase in the total number of students studying within the University’s dotted around Manchester’s city centre (HESA, 2018). The City Centre Council Ward data referred to above shows how such increases connect directly with the city centre’s residential composition (MCC, 2018a).

The marketisation of UK universities and the related studentification of UK cities have also involved a sharp increase in the number of international students entering HE institutions. As Foskett (2011, p. 25) explains:

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[9] These included The Victoria University of Manchester, The University of Manchester Institute of Science & Technology, The Manchester Metropolitan University, Royal Northern College of Music, The University of Salford, Bolton Institute of Higher Education, Salford College of Technology (HESA, 2018).

[10] The drop from seven to five was a consequence of The Victoria University of Manchester and The University of Manchester Institute for Science and Technology combining to become the University of Manchester, and the Salford College of Technology becoming a part of The University of Salford (HESA, 2018).

> Universities have seen significant expansion of 'overseas' student numbers… In the mid 1980s students from outside the UK numbered approximately 20,000, while by 2008 this had grown to 350,000.

Following this trend, it is estimated that 19,000 international students were studying at either the University of Manchester, Manchester Metropolitan University, the University of Salford or the University of Bolton in 2017 (Invest in Manchester, 2018).

Acknowledging the significance of such figures, John (MCC employee, and planning and regeneration professional) spoke of the relationships between the city's residential development and the growing number of international students living in Manchester. As he explained:

> We live in a dynamic unscripted world, and there are international forces out there, Hong Kong, China, India, you know wherever, and we talked before about student flats and paying £3,000 and £4,000 for rent, who could have foreseen that? (John, MCC employee, and planning and regeneration professional)

Likewise, Dan recognised the importance and influence of the city's universities on Manchester's built form and changing composition. He referred specifically to the significance of Manchester having the 'biggest educational campus in Europe… [and a] graduation retention rate [which] is incredible' (Dan, MCC employee, and planning and regeneration professional). John and Dan thus drew links between Manchester city centre's residentialisation and the success of the city's universities – institutions which have expanded during a period of marketisation that intensified at the turn of the millennium, with political focus aimed at dramatically increasing student numbers (Lunt, 2008).

Manchester city centre's studentification, which fits with and is arguably a symptom of a broader marketisation of UK universities and was enacted through the work of successive governments, intersected with the 1996 introduction of the BTL mortgage and the emergence of an institutionalised concern with constituting 'liveable' cities – a concern evidenced, for example, in the work of the Urban Taskforce leading into the turn of the millennium (Rae, 2013). Accordingly, I have suggested that Manchester city centre's residentialisation is usefully interpreted as a thoroughly entangled outcome of multiple trends and related flows of people and investment. By introducing and connecting such flows, I have interpreted Manchester city centre's residentialisation, since the turn of the millennium, as a product of intersecting 'global-local' currents that collided and layered over time, reacting and producing trends in land use change. Thus, although taking inspiration from Massey (1991, 2005), I have articulated an account of Manchester city centre's residentialisation which concerns the symbiosis of different elements that knot and combine, producing accelerated periods of development over time.

Continuing to work with and articulate a specification of Massey's (1991, 2005) conceptualisation of space, in the next section I make connections between two very different international events and Manchester city centre's land use change since 1984. The effects of specific events on a place's development and change are not emphasised in Massey's (1991, 2005) work. This is not simply an empirical omission, Massey (1991, 2005) draws attention to duration and ongoing change, as opposed to the effects of specific and dramatic moments. The coming discussion specifically suggests that Manchester city centre's land use change, between 1984 and 2014, has also been informed by particular and somewhat unique event-oriented moments, around which land use change accelerates.

The effects of two international events on Central Manchester's land use change

During the interviews I conducted with planning and regeneration professionals, the effects of the 1996 IRA bomb and delivery of the 2002 Commonwealth Games were frequently connected with the city's contemporary renaissance. Although both international, the events were very different. The bomb caught the city by surprise and required an immediate planning response (Williams, 2000). It was also a part of 'The Troubles', a period of intense conflict between the IRA and the British government, which lasted from the 1960s to the late 1990s (English, 2003). During 'The Troubles', the IRA attacked several English cities. Brighton, London, Birmingham, Warrington and Guildford were all targeted during the conflict (English, 2003). Emphasising the international dimensions of the conflict, Bell (1970) notes that the IRA were supplied with munitions by Libya's Colonel Gaddafi, while Hanley (2004) and Cochrane (2007) refer to the significant financial and political roles played by Irish-Americans allied to the republican cause. The Manchester bomb thus formed part of an international political struggle, played out in the city centre in the summer of 1996. The Games, by contrast, were the product of a longer-term aim of bringing a major international sporting event to the city (Law, 1994; Smith and Fox, 2007). While the bomb represented an unexpected demolition of a large part of the city's commercial space for the local authority, the Games were a planned affair, around which capital was mobilised to position Manchester on the global platform (Carlsen and Millan, 2002).

In this section, I suggest in contrast to the ongoing liberalisation of planning or the longer-term combining of flows of people and investment, which I linked with the city's residentialisation, that the bomb and the Games represent punctuated moments which were not made in Manchester but nevertheless stimulated and accelerated processes of land use change and development in the city.

The 1996 IRA bomb

On the 15th of June 1996, the IRA detonated a 3,300 lb bomb in the centre of Manchester (Holden, 2002). It was the largest bomb detonated on British soil since WW2 (Holden, 2002; King, 2006). Image 3 represents the devastation caused by the bomb (Payne, 2014).

Image 3: The aftermath of the IRA bomb in Central Manchester (Payne, 2014)

The bomb affected 1,200 buildings, resulting in 672 displaced businesses (Batho et al., 1999). '49,000 square meters of retail space and 57,000 square meters of office space… [were] immediately decommissioned' (Batho et al., 1999, p. 221). As Batho et al. (1999, p. 221) explain:

> Around a dozen major buildings of either functional and/or historic significance suffered serious structural damage, half of which required demolition… In addition, many other elements of the city's infrastructure were affected with fears about utility fractures, major roads damaged, the city's largest bus terminal closed permanently, two multi-storey car

> parks shut temporarily (for two weeks) and key streets closed (many for 18 months).

The damage wrought by the blast required an immediate urban planning response (Williams, 2000; Williams et al., 2000). This response took shape through the production of a masterplan framework, which, as John explained, was a major challenge: ‘to re-masterplan the commercial heart of a city is a big step’ (John, MCC employee, and planning and regeneration professional).

The Manchester Millennium Taskforce (MMT), a public-private hybrid, was established to deal with the planning challenges posed by the effects of the explosion (Williams, 2000). Within four weeks of the blast and as part of the organisation’s work, the MMT announced an International Urban Design Competition, which sought an architectural plan for the impacted area (Holden, 2002). EDAW, an international architectural design firm, originating from San Francisco, won the competition (Williams, 2000). The result of the ‘high profile international design competition… [informed the] Masterplan Framework' (MCC, 2010a, p. 33). The Masterplan Framework was complemented by:

> Supplementary Planning Guidance (SPG) which [set] out the wider planning context within which the redevelopment of the bomb damaged area [would] take place. The SPG [was] based on policies in the Manchester Plan [(1984)] and the principles of the Guide to Development in Manchester [(1997)]. (MCC, 2010a, p. 33)

The recovery from the bomb thus built on and was informed by the principles set out in *Manchester City Centre Local Plan* (1984), a publication which, as discussed, conformed with a broader national liberal-turn in planning practice.

For Holden (2002, p. 134), the techniques mobilised to recover from the bomb further represented ‘a pivotal moment in the city’s revolution of partnership and revitalisation’ and reflected a wider embrace of entrepreneurial techniques of governance, which link with a broader cutting of red tape and the associated and ongoing adoption of a liberalised approach to planning. The entrepreneurial approach Holden (2002) refers to was echoed by Dan and John (MCC employees, and planning and regeneration professionals), who both suggested that the bomb provided an opportunity to draw capital into the city centre for purposes of regeneration.

For Dan, 'everything really coalesced in the city centre on the back of the bomb' (Dan, MCC employee, and planning and regeneration professional). John further explained that the bomb specifically provided an opportunity to reorganise the city centre and in particular an unsightly and obdurate concrete enclave, known as Shambles Square, which was the product of a planning paradigm orientated around zoning:

> It was a concrete nightmare called Shambles Square. And, it was a 'shambles'… Some horrible sixties thing…. literally a stone's throw away from the Royal Exchange. So, the planning in the late sixties or fifties allowed that to happen. Because that was probably all that the building world could do at that time anyway. But the IRA did us all a favour. Marks and Spencer went, the Royal Exchange needed to be refurbished, St Ann's Square needed to be refurbished, St Ann's Church was affected. Shambles Square got knocked down. (John, MCC employee, and planning and regeneration professional)

As John further explained, the opportunity he spoke of was afforded because the blast provided a means of accessing an EU crisis fund. By December 1996, £21.5 million of European Development Funding had been made available to the Manchester Millennium Task Force (Hansard, 1996). This contributed to a rebuilding project that had an estimated total cost of over £500 million by the turn of the century (Holden, 2002).

The size of the recovery project is captured in the aims of the Manchester Millennium Task Force Masterplan Framework, which also reflect an interest in producing a 'liveable' city. As illustrated by Williams (2006, p. 197), in reference to the 1996 Millennium Task Force objectives, the framework aimed at:

- The restoration and enhancement of the retail core
- The simulation and diversification of the city's economic base
- The development of an integrated transport strategy
- The creation of a quality city core fit for the twenty-first century
- The creation of a 'living' city by increasing its residential population
- The creation of a distinctive Millennium Quarter

The expenditure plan - outlined in the MCC (2002) *Task Force Final Report* - provides further detail regarding the scale of redevelopment following the blast. There was, inter alia, £311 million spent on restoration and enhancement of the retail core of the city, £10 million on residential development and £41.4 million on the creation of a distinctive Millennium Quarter (MCC, 2002). Figure 10, which is a table produced by Williams (2006, p. 203) using MCC (2002) information, outlines what the Manchester Millennium Task Force project produced.

	Completed master plan
New quality retail floor space	81,000 m^2
Damaged retail space back trading	23,225 m^2
New leisure floor space	45,107 m^2
New quality offices	6,000 m^2
New hotel accommodation	164 beds
New civic and/or cultural space	8,416 m^2
Enhanced streetscape and/or new squares	34,000 m^2
New residential units	150 units
Listed buildings repaired or restored	5 buildings
CCTV and/or community safety initiative	1 initiative
New city centre management scheme	1 scheme
Missing links in inner relief route	3 sections
New business start ups	250 businesses
Car parking spaces upgraded	1,500 spaces
Bus priority measures	20 measures
Traffic calming schemes	10 schemes
New permanent jobs created	1,400 jobs
Temporary construction jobs, person years	7,000 jobs
New public parks/green spaces	8,300 m^2
New trees	200 trees
New transport interchange	1 interchange
Improved metro-link stations	2 stations
Private sector leverage	£490 m

Figure 10: Outcomes related to the Manchester Millennium Task Force (Williams, 2006, p. 203)

The recovery from the bomb and the regeneration of the effected area also acted as the 'strong catalyst for investment elsewhere within the city centre' (Williams, 2006, p. 204). In 1999, Hetherington (1999) estimated, for example, that by 2000 the rebuilding bill 'could easily top £1bn, with big retailers, leisure companies, developers and housebuilders queuing up to invest in a city which has reinvented itself'.

The response to the bomb thus built on a broader liberalised approach to planning. Moreover, the bomb provided an opportunity to focus on creating a 'living city', an aim which fitted with the emergence of a wider discursive institutional concern with constituting 'liveable' cities (Ley, 1990; Evans, 2002; Mellon, 2009). Yet, although the response to the effects of an international conflict reflected equally international trends in planning practice, the bomb and the nuances of its material effects were in some ways unique to Manchester and posed a specific and situated set of challenges and opportunities. For this reason, the inimitability of the bomb stands out against the longer-term national liberalisation of planning, the cutting of red tape, the availability of BTL mortgages, the ongoing marketisation of HE and related processes of studentification. Looking back, the bomb thus represents a unique moment in the city's history, which stands out against an ongoing set of changes and trends already connected in this chapter with Central Manchester's development and land use change since 1984.

The 2002 Commonwealth Games

Like the IRA bomb, the 2002 Manchester Commonwealth Games drew multiple international actors into Manchester's city centre, producing and informing land use change (Carlsen and Milan, 2002; Smith and Fox, 2007; Cook and Ward, 2011). The aim of bringing an international sporting event to Manchester was long in the making and well underway before the bomb exploded in 1996. The Games specifically built on three failed bids to host the Olympic Games in Manchester, the first in 1992, the second in 1996, and the third in 2000 (Cook and Ward, 2011). The 2002 Commonwealth Games were therefore not, like the bomb, a shock for the local authority. Instead, the 2002 Commonwealth Games were part and parcel of a longer-term purposeful project to position Manchester on a global stage and attract investment into the city.

Dan (MCC employee, and planning and regeneration professional) touched on how the 2002 Commonwealth Games were part of a longer-term project and further what hosting an international event meant for Manchester City Council (MCC):

> Things coalesced around an Olympic bid, as Manchester [MCC] decided it wanted to reinvent itself and we had to do something big and bold and grand, and get ourselves out there on a world stage, and get our name known around the world. You know we had this audacious process which was about Manchester… hosting the Olympic Games, and it was 1992 our first vision… To be honest with you, the city [MCC] never wanted to host the Games at that time. What we wanted to do was [create] a

> magnet for investment. And, we attracted so much government funding on the back of that, which allowed us to develop a vision for what the city might be. (Dan, MCC employee, and planning and regeneration professional)

John echoed Dan's perspective:

> Manchester, in the late 1990s or mid 1990s, you know whether it be through bids for the Commonwealth Games or… other bids, on the international stage, we were saying… we've got something. (John, MCC employee, and planning and regeneration professional)

Together, these comments reflect the belief that 'hosting the… Commonwealth Games… would help to firmly (re)connect Manchester into the global economy… providing [a]… platform… [to] encourage gentrifiers, investors and tourists' (Cook and Ward, 2011, p. 2520).

The 'international' and 'world' stages, referred to by Dan and John (MCC employees, and planning and regeneration professionals), further regard what it means and what it takes to host an international sporting event, such as the Commonwealth Games. In this respect, the Commonwealth Games Federation (CGF) outlines strict expectations and rules concerning the hosting of the event. These are distilled in documents, such as *The Candidate City Manual* (see for example: CGF, 2018a), the Host City Contract and *The Constitutional Documents of the Commonwealth Games Federation* (CGF, 2018b). In the *Candidate City Manual* there are, for example, fifteen themes around which host city obligations are shaped (CGF, 2018a). These include:

- A commitment to design a clear Games vision and concept
- A commitment to producing an event which is environmentally sustainable

- A commitment to developing the necessary transport infrastructure and stadia with agreed minimum capacities
- A commitment to guarantee the finances required to deliver the Games (CGF, 2018a)

In reference to the last commitment, the host city must 'ensure the financing of all major capital infrastructure investments required to deliver the Commonwealth Games… [and] cover a potential economic shortfall of the OC [Organising Committee]' (CGF, 2018a, p. 50). Durban's recent failure to hit key targets and provide the necessary capital to deliver the 2022 Games, resulted in the city losing the event (BBC, 2017). A case in point, which underscores the significance of meeting the CGF's strict financial expectations.

Besides the official commitments and obligations outlined by the CGF, delivering the Commonwealth Games also involves conforming with a broader history concerning what it means to successfully host an international sporting event. The Sydney Olympics were, for example, 'a significant factor in shaping Manchester's Games' (Manchester 2002[11] (M2002), 2002a, p. 36). As explained in the M2002 (2002a, p. 36) *Post Games Report Volume 1*:

> The Sydney Olympics… were the most successful in the history of the Olympic movement and set new standards for international multi-sport events. Plans for Manchester's Games were already ambitious in terms of available budget but the Olympics raised the standard to such a point that these plans had to be revised if Manchester's Games were to be seen as a success. Staff from M2002 went on a fact-finding mission to Sydney in an observer capacity and experienced first hand the success of

[11] Manchester 2002 Limited was the public-private organisation established in 1996 to manage the delivery of the 2002 Commonwealth Games (Cook and Ward, 2011).

> the Games. M2002 used this opportunity to recruit experienced personnel from Sydney.

This connection between Manchester and Sydney emphasises how hosting an international event, such as the 2002 Commonwealth Games, ties host cities into a set of expectations and norms about what it means to craft and deliver a successful mega-event. A point which is reflected in the constant comparisons, made in Post Games Reports (M2002, 2002a, 2002b, 2002c), between the 2002 Manchester Games and the Sydney and Barcelona Olympics. As a consequence of such links, the 2002 Commonwealth Games were not a product of the city. The 2002 Commonwealth Games can instead be understood to have landed in the city with a host of associated expectations and commitments, which informed and depended on land use change in and beyond Central Manchester.

In terms of the material effects of the Commonwealth Games on the city's land use change and development, a series of connections can be identified. As many have shown, the Commonwealth Games were explicitly used to enact regeneration (Carlsen and Millan, 2002; Ward, 2003; Cook and Ward, 2011). The Games were, for example, 'used locally as… part of the wider redevelopment of East Manchester' (Ward, 2003, p. 123). The connection between the Games and the regeneration of East Manchester was established from the outset by M2002 (2002a, p. 23):

> For MCC the Games were a key point in the regeneration of East Manchester and a means of levering significant investment into the area. They were set in the context of the wider and much longer term local regeneration strategy that had been an accepted regional and national priority since the mid 1990s. Sustainable after-use of venues was also an important and well established priority. East Manchester had also become the focus for several initiatives (New Deal for Communities, SRB5, Urban Regeneration Company) which used the Games as a focal point, adding to the critical mass of impact.

Land use change in East Manchester connected with the 2002 Games involved the 'reclamation of a former 146 hectare derelict site…, £127 million investment in new sports facilities…, [and a] £45 million investment in leisure and entertainment (M2002, 2002a, p. 157). Of the sports stadia developed in the area, the 48,000-seater Manchester City Stadium, which now accommodates Manchester City Football Club, was the largest (M2002a). This stadium, the National Squash Centre, the Regional Athletics Arena, the Manchester Velodrome and a tennis centre form the wider Sportcity complex, a key legacy of the 2002 Commonwealth Games, which was largely financed by National Lottery Funding (M2002, 2002c).

Beyond the direct connections between the Games and the development of land in East Manchester, the build-up to and delivery of the event also involved wider and entangled flows of investment and people into the city, which informed and supported different forms of land use change. It is estimated, for example, that across the wider Manchester region, the Games stimulated the development of 51,223 m2 of floorspace and the reclamation of 40 hectares of land (M2002, 2002c). The Games also involved the use and revamping of parts of the University of Manchester campus as a means of creating an athletes' village (M2002, 2002a). Further afield, the delivery of the Games connected with the development of tourist attractions, such as the £91.4 million Discovery Park scheme in the centre of Liverpool (M2002, 2002c). Accordingly, the effects of the Games, in terms of enduring land use change, were felt at a wider regional scale.

Reading the events and trends in conjunction

The links between the city's regeneration and the 2002 Games largely took shape between 1995 and 2002. Preparation for the Commonwealth Games, although longer in the making and related to three failed Olympic bids, began taking shape in material form a year before the unexpected detonation of the

IRA bomb in 1996 (M2002, 2002a). The recovery from the bomb and the delivery of the Games therefore overlapped.

When read in combination, these events can be understood to have intersected and knotted together, acting as punctuated moments that further built on a longer-term embrace of a liberalised approach to planning and an associated entrepreneurial-turn in governance - shifts which have been directly linked with each event (Williams, 2000, 2002; Ward, 2003). The timespan of the Games and the recovery from the bomb also coincided with the introduction of the BTL mortgage, in 1996, and a period linked with the marketisation of HE, which I have connected, drawing on interview material and secondary sources, with processes of city centre residentialisation. The emergence of a contemporary liveable cities agenda, captured in key national government initiatives and policies (Urban Task Force, 1999; Department of the Environment, Transport the Regions, 2000), also coincided with the ongoing preparation for the 2002 Commonwealth Games and the recovery from the IRA bomb.

Such intersections and conjunctions are central features of my account of Central Manchester's land use change since 1984. Although these intersections and the resultant knots occurred in Manchester, they were not a product of the city itself. Indeed, the various policies, trends, events, flows and concatenations discussed in this chapter were all part of extended and geographically dispersed relationships. Moreover, the details of timing and the different forms of 'not made in Manchester' have consequences for the constitution of electricity demand, and for how shifts in practice, represented by land use change, might be conceptualised.

More than multiplicity and open-ended change

My account of the links between Central Manchester's land use change since 1984 and the wider liberalisation of planning, the effects of the introduction of the BTL mortgage, the marketisation of HE, the spread of a 'liveable' cities agenda and the impact of two international events, draws attention to the different types of intersections that underwrite a city's uneven change over time. By focusing on the city's uneven development and explaining periods of relative continuity and moments of change, I move beyond simply producing a Massey (2005) inspired account premised on 'interrelatedness, heterogeneity, and openness' (Schatzki, 2010b, p. 197). The interrelatedness and heterogeneity Massey (1991, 2005) writes of is held between a multiplicity of 'material-practices'. As she explains:

> Space [is] the sphere of the possibility of the existence of multiplicity in the sense of contemporaneous plurality; as the sphere in which distinct trajectories coexist; as the sphere therefore of coexisting heterogeneity. Without space, no multiplicity; without multiplicity, no space. (Massey, 2005, p. 10)

Accordingly, for Massey (1991, p. 28), space is 'absolutely not static'. As Schatzki (2010b, p. 198) explains, with regards to Massey's (2005) work, 'space… is forever under construction'.

In light of the points raised in this chapter, however, Massey's (1991, 2005) conceptualisation of space leans toward a generality that loses sight of the mixing and symbiosis of trends and events, which can be usefully connected with pronounced moments and periods of land use change and development. As outlined, Manchester city centre's development has not unfolded as an ongoing continuum of relative change. Different policies, trends and events can be understood to intersect and knot over time contributing to the formation of distinct periods of development, such as Central Manchester's pronounced residentialisation since the turn of the millennium.

Developing this point, my analysis in Chapter three foregrounds periods of relative continuity in the Northern Quarter (NQ), with, for example, few instances of land use change recorded in the area between 1990 and 1997 (see Chart 2 in Chapter three). Such continuity is juxtaposed with periods of accelerated change in the use of land and by implication the anchoring of electricity-demanding bundles of practices in the area. For example, the accumulation of residential development in the NQ which accelerated after the turn of the millennium. Thus, while the account I have articulated of Manchester city centre's development acknowledges 'city building is a continuous, ongoing process [and that] cities are in a process of being built and rebuilt all the time' (Hommells, 2005, p. 323), it also recognises and works through the lumpiness of local events, and the uneven conjunctions of trends and ambitions imagined and developed beyond the city itself.

My discussion of the uneven development of space in Central Manchester specifically has consequences for understanding the spatial and temporal organisation of electricity-demanding practices. Just as development takes place unevenly and over time, so does the anchoring of electricity-demanding practices. Specific intersections, such as those described above, further amplify and accelerate particular patterns of urban development (like Manchester city centre's residentialisation since the turn of the millennium) and the spatial composition of electricity-demanding bundles of practice.

Summary and recovering the missing masses

In this and the previous chapter, I focused on the spatial organisation of practices in the Northern Quarter (NQ) and Central Manchester since 1984. In combination, these chapters provide an account of the uneven spatial configuration of land use and thus electricity demand in the city over time, which I have connected with periods of relative continuity, juxtaposed against more pronounced and dramatic moments of change in certain directions. As it stands, the electricity system is somewhat missing. The following questions thus remain unanswered:

- How has the NQ’s and Central Manchester’s residentialisation since the turn of the millennium affected and depend on the management and organisation of the electricity system?

- How has the NQ’s and Central Manchester’s broader land use change, since 1984, affected and depended on the electricity system?

These questions are taken up in the two subsequent chapters. In the coming chapter, I focus explicitly on an instance of large-scale investment in Electricity North West’s (ENW) distribution network: the 2009 development of the Central Manchester 33 kV Primary Substation. By studying how this substation came to be required and the rationales that underpinned its constitution, I am able to articulate connections between the NQ’s and Central Manchester’s development, the related anchoring of electricity-demanding -practices, and the organisation of the electricity system. As with this chapter, continuity and moments of change characterise the connections I make between Central Manchester’s development and the ongoing physical organisation of the electricity system. Chapter six instead concerns the wider organisation of the electricity system and how this relates to Central Manchester’s ongoing changing form and function.

Chapter five: The Central Manchester 33 kV Primary Substation

Introduction

This chapter is about the 2009 development of the Central Manchester 33 kV Primary Substation. The Central Manchester Primary is one of only two 33 kV substations built in the city centre since 1972. I focus on this relatively rare instance of largescale infrastructural investment as a means of exploring how the Northern Quarter's (NQ) and Central Manchester's land use change, and the related anchoring of electricity-demanding practices in the city centre, have depended on and affected the organisation of the electricity network.

I work with and mobilise the concept of 'technological frames' (Orlikowski and Gash 1994; Bijker, 1995; Aibar and Bijker, 1997). Following Bijker (1995), a frame is understood to form a meaningful and prescriptive rationale through which an artefact is defined and given meaning by social actors and/or groups. Drawing on expert interviews with Electricity North West (ENW) employees and a range of maps, spreadsheets, schematic diagrams and other company publications, I position the Central Manchester Primary within two coexisting explanatory and constitutive frames.

In the first instance, I interpret and frame the Central Manchester Primary as a consequence of ENW having to react to Manchester's ongoing land use change and a related accumulation of applications for connection, which meant existing network capacities and thresholds could be breached in 2008/09. I argue, in turn, that the Central Manchester Primary can be conceptualised and positioned within a 'reactive' frame and interpreted as a 'lumpy' consequence of how the changing composition of land and the anchoring of bundles of practices depends on and affects the material organisation of the electricity network over time. Framed in this way, the relationships between practices and the network reflect material intersections that build up and accumulate over time causing distinct network modifications - in the case studied, taking the form of large-scale investment in the Central Manchester Primary. I also position the Central Manchester Primary in a coexisting 'proactive' frame, suggesting that the substation's development represents a response to longer-term visions and expectations of electricity demand in and beyond Manchester. This 'proactive' framing is linked with the visions of local and national political actors, their related economic growth calculations, expected increases in population, and associated estimates concerning the adoption of electric vehicles (EV) and heat pumps. Following Spurling (2019, p. 137), who discusses town planners' responses to changing mobility practices in Stevenage, I describe the lumpy effects of the 'balancing [of] visions of long-term futures… with more pressing challenges of the here and now'.

My description of the 'reactive' and 'proactive' framing of the Manchester Central 33 kV Primary has implications for my understanding of 'the processes that involve the negotiations and attempts at undoing the sociotechnical status quo' of infrastructure (Hommels, 2005, p. 342). I suggest that the longer-term expectations and pressing challenges of the here and now, which ENW handle, develop and respond to, need to be fully integrated into understandings of how the electricity network's obduracy and stability are challenged and reasserted over time. Traditionally, the challenges, objectives and aims of specific actors and organisations have formed a focal point of research concerning the obduracy and stability of various networks (Winner, 1980; Hughes, 1983; Latour, 1996; Graham and Marvin, 2001; Guy et al., 2010; Moss and Francesch-Huidobro, 2016). In contrast, I emphasise links between the expected changing form and function of land, the dynamics that underpin such changes, and the HV network's extension. Subsequently, I suggest that focusing on the types of flows, trends and intersections, which I connected with the NQ's and Central Manchester's land use change since 1984 and the related anchoring of practice bundles (Chapter three and Chapter four), provide a productive means of conceptualising how the obduracy and stability of the electricity network are challenged and reasserted over time.

The chapter is structured in the following way. Firstly, I situate the Manchester Central Primary by providing detail about the design, location and role of the substation. This context emphasises why studying the Central Manchester Primary's development offers a particularly useful opportunity to unpack and explore the connections between land use change and the organisation of the electricity network. I subsequently set the ground for my descriptions of the 'reactive' and 'proactive' framing of the Central Manchester Primary, by explaining why and how I work with 'technological frames' as an analytical concept (Orlikowski and Gash 1994; Bijker, 1995; Aibar and Bijker, 1997). Having established the key conceptual and analytical foundations of the chapter, I articulate my account of the 'reactive' and 'proactive' framing of the Central Manchester Primary. In the penultimate section, I present the implications of the 'reactive' and 'proactive' framing for thinking about how practices and the electricity system relate over time and, in conversation with Hommels (2005), consider what my analysis means for conceptualising infrastructural obduracy and stability. In the final section, I provide a summary and pose a series of questions concerning the wider organisation of the electricity system, which are raised as a consequence of this and the previous empirical chapters.

Situating the Central Manchester 33 kV Primary Substation

As its name suggests, the Central Manchester Primary is located in Central Manchester (see Figure 11). The primary is positioned between Fairfield Street and Travis Street, on a piece of land previously used in the nineteenth and early twentieth centuries for housing, then as an engineering works between 1922 and 1955, and since 1984 as a carpark (MCC, 2007). The substation can be viewed from platform fourteen of Manchester Piccadilly Train Station (see Image 4 and Image 5).

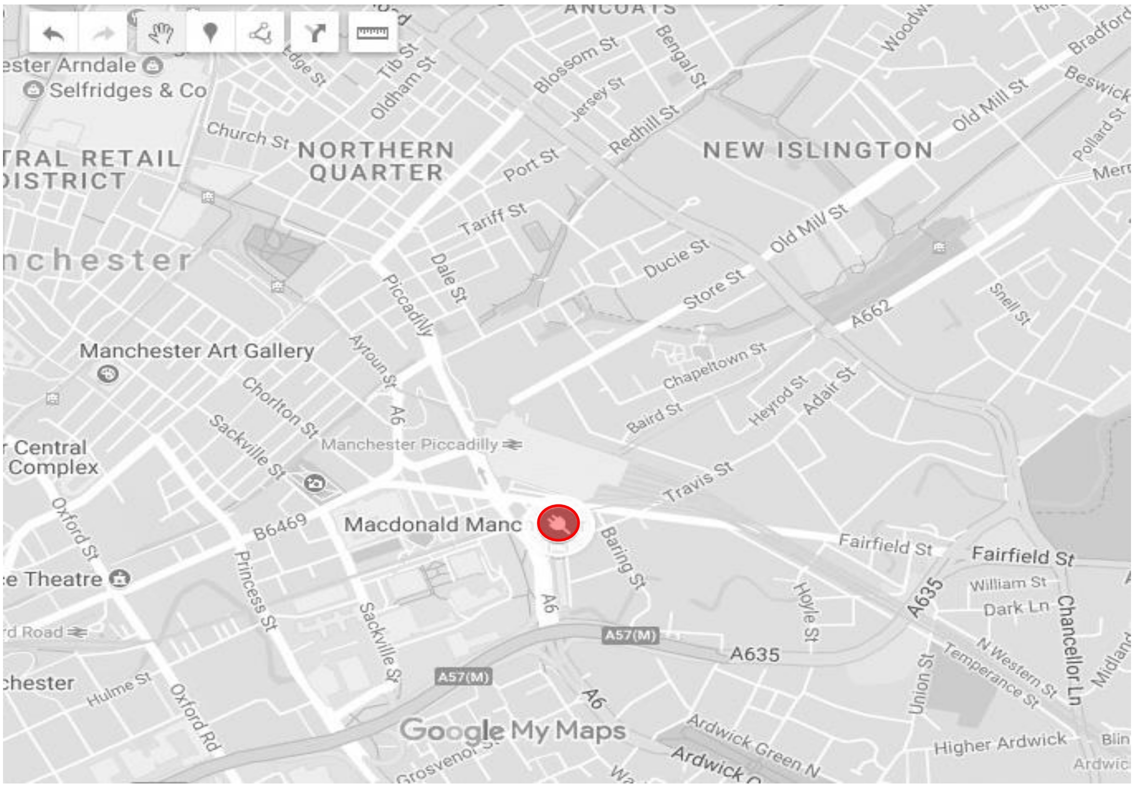

Figure 11: The location of the Central Manchester 33 kV Primary Substation

Image 4: Central Manchester 33 kV Primary Substation as viewed from Platform Fourteen of Manchester Piccadilly Train Station

Image 5: Central Manchester 33 kV Primary Substation (Independent Quantity Surveyors, 2017)

The design of the building that houses the substation is consistent with and maintains the general invisibility of energy infrastructures; one would not necessarily know it housed a key piece of Central Manchester's high voltage (HV) electricity network (Star, 1999; Shove, 2000; Walther, 2016). This ambiguity was purposefully enacted by the design company, which, acting under the planning guidelines of the local authority, designed a structure that blended into the surrounding area (MCC, 2007). The Central Manchester Primary is consequently an intriguingly nondescript artefact, yet also crucial to the distribution of electricity to a growing city (Deloitte, 2018, 2019). Made of COR-TEN weathered steel, the building houses a 33 kV brick-built switchgear and two transformers (IQS, 2017).

The Central Manchester Primary was commissioned in 2007 and completed in 2009, at an estimated cost of £1.8 million (MCC, 2007; Independent Quantity Surveyors (IQS), 2017). The primary is one of 363 33 kV substations managed and maintained by ENW across the geographic region the company serves (ENW, 2018a). Yet, the Central Manchester Primary's age also places it within a much smaller bracket of 33 kV substations built in more recent times (ENW, 2017a, 2017b). As Figure 12 represents, the majority of ENW's assets were installed between 1950 and 1975 (ENW, 2017b, p. 9). This period of intensive investment in the electricity network, which reflects a broader project of nationalisation and arguably an ethos of universal provision (Graham and Marvin, 2001), is also evident in the composition and age of HV network assets in Central Manchester. Of the seven 33 kV primaries in the city centre, five were built between 1956 and 1972, with only two developed since the turn of the millennium: the Bridgewater Primary in 2000 and the Central Manchester 33 kV Primary Substation in 2009.

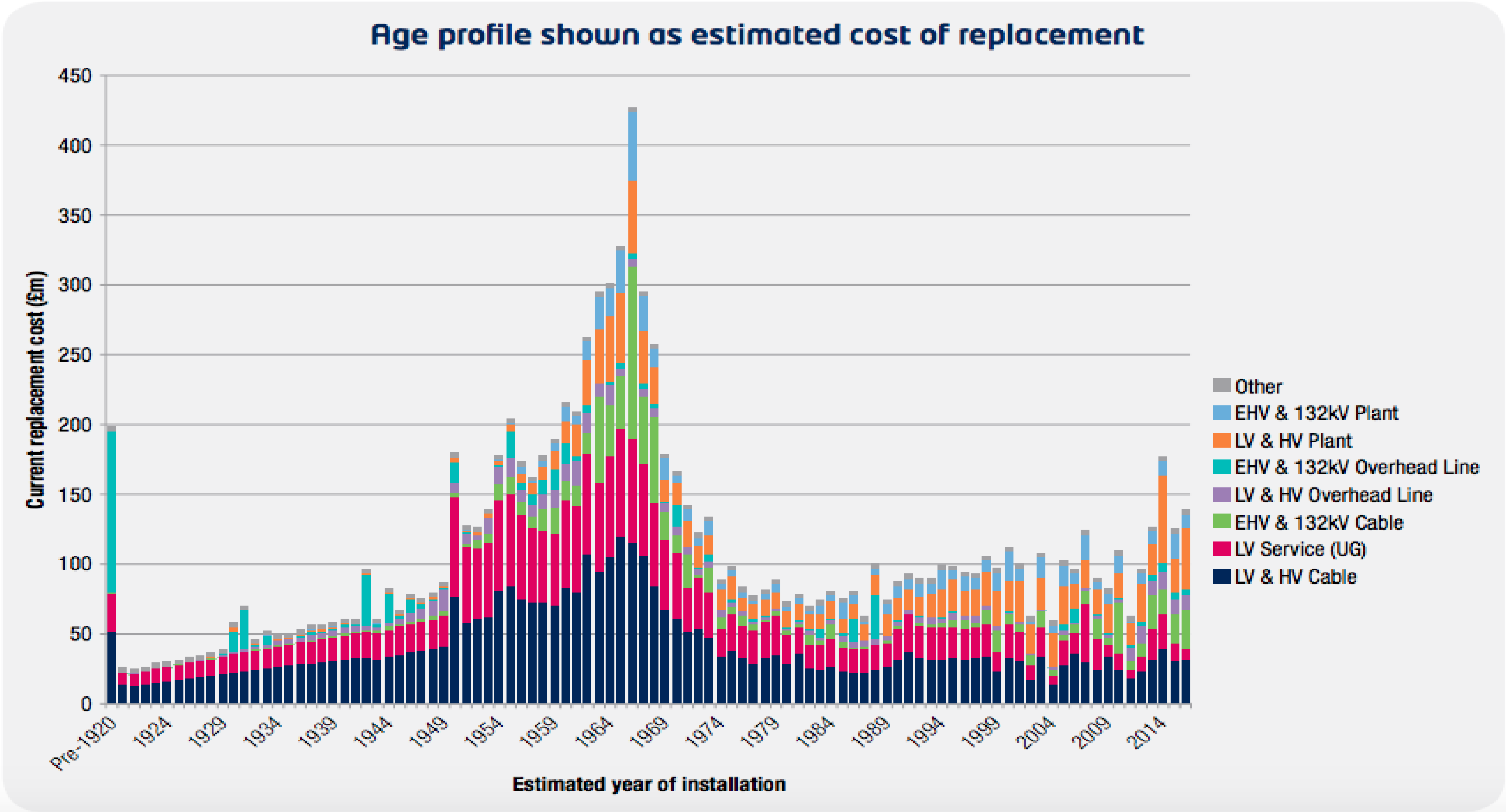

Figure 12: Age profile of ENW's assets according to year of installation and current replacement cost (£m) (ENW, 2017b, p. 9)

The Central Manchester Primary is connected to the ‘Stuart Street Grid’ and Bulk Supply Point (BSP) (Figure 13). The Stuart Street site was originally a coal-fired power station built in 1900 (Frost, 1993). Decommissioned in 1975, the Stuart Street BSP now functions as a 132 kV substation, which feeds seven 33 kV primary substations.

When the network is operating as it should, electricity is received by the Stuart Street BSP from the Stalybridge Grid Supply Point (GSP). A GSP is a substation that receives electricity from the National Grid transmission system. Electricity is transmitted from the Stalybridge GSP to the Stuart Street BSP at a transmission rate of 132 kV. At Stuart Street, the voltage is stepped down to 33 kV and fed through to the seven connected 33 kV substations, one of which is the Central Manchester Primary. At the Central Manchester Primary, the voltage is stepped down again, this time to 6.6 kV. Before arriving at the point of consumption, the electricity that travels from the Central Manchester Primary is transformed, once more, but this time the voltage depends on the requirements of the end user. Domestic customers, for example, typically receive electricity at 240 V.

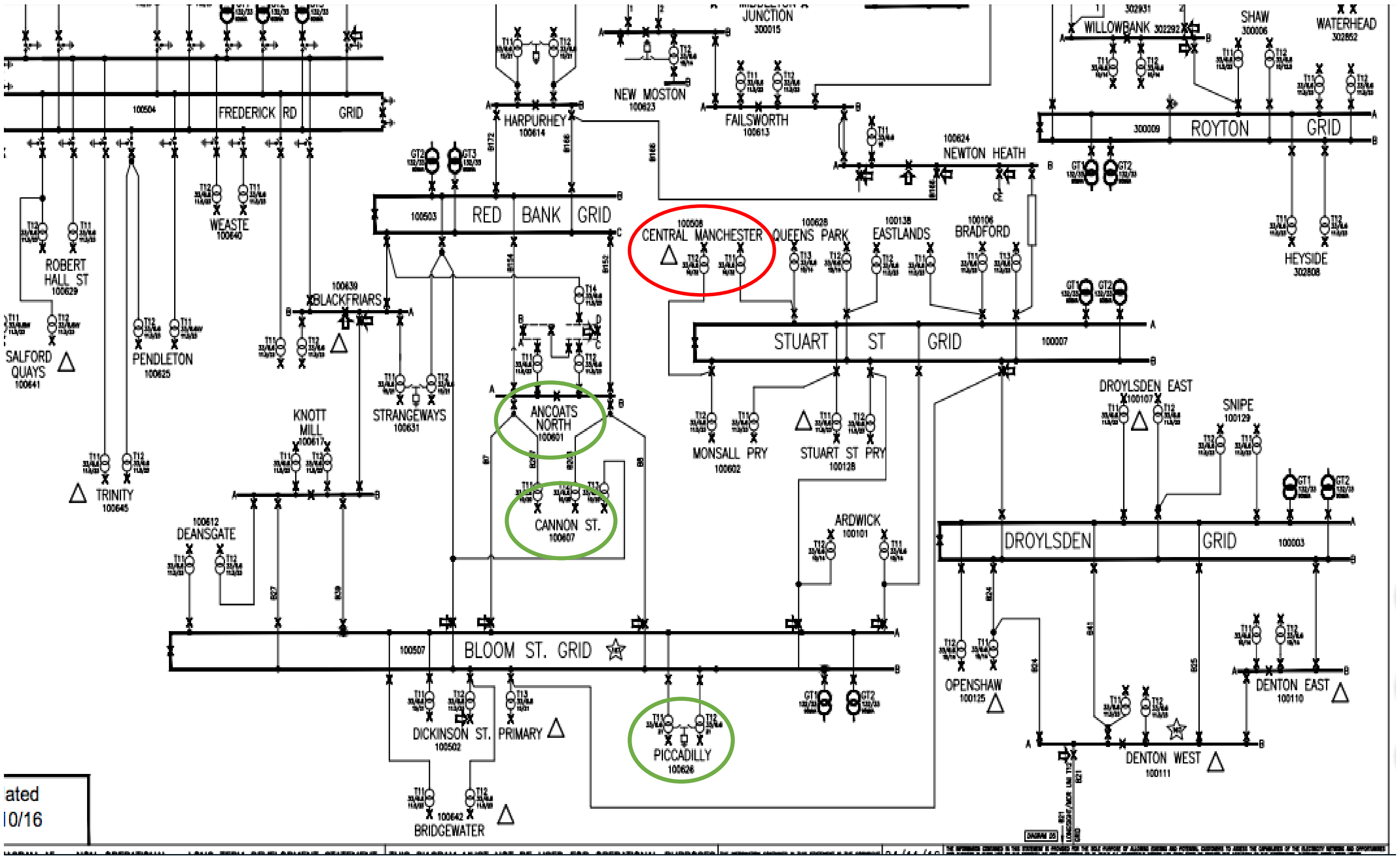

Figure 13: Segment of ENW's schematic diagram of the 33 kV HV network in North Manchester

To illustrate such connections, the 6.6 kV 'City Lofts' substation is marked on Figure 14 and Figure 15 in a blue circle. Figure 14 and Figure 15 show segments of the 'North Manchester 6.6 – 11 kV' schematic diagram. The City Lofts substation is situated in the NQ, in the basement of a mixed-use block comprising forty-nine residential units and ground floor commercial offerings, listed in the original planning application under restaurants, bars and retail (MCC, 2000). The City Lofts development was granted planning permission in 2000 and it is typical of the types of land use changes discussed in the previous two chapters of this thesis and characteristic of the historical development of Central Manchester.

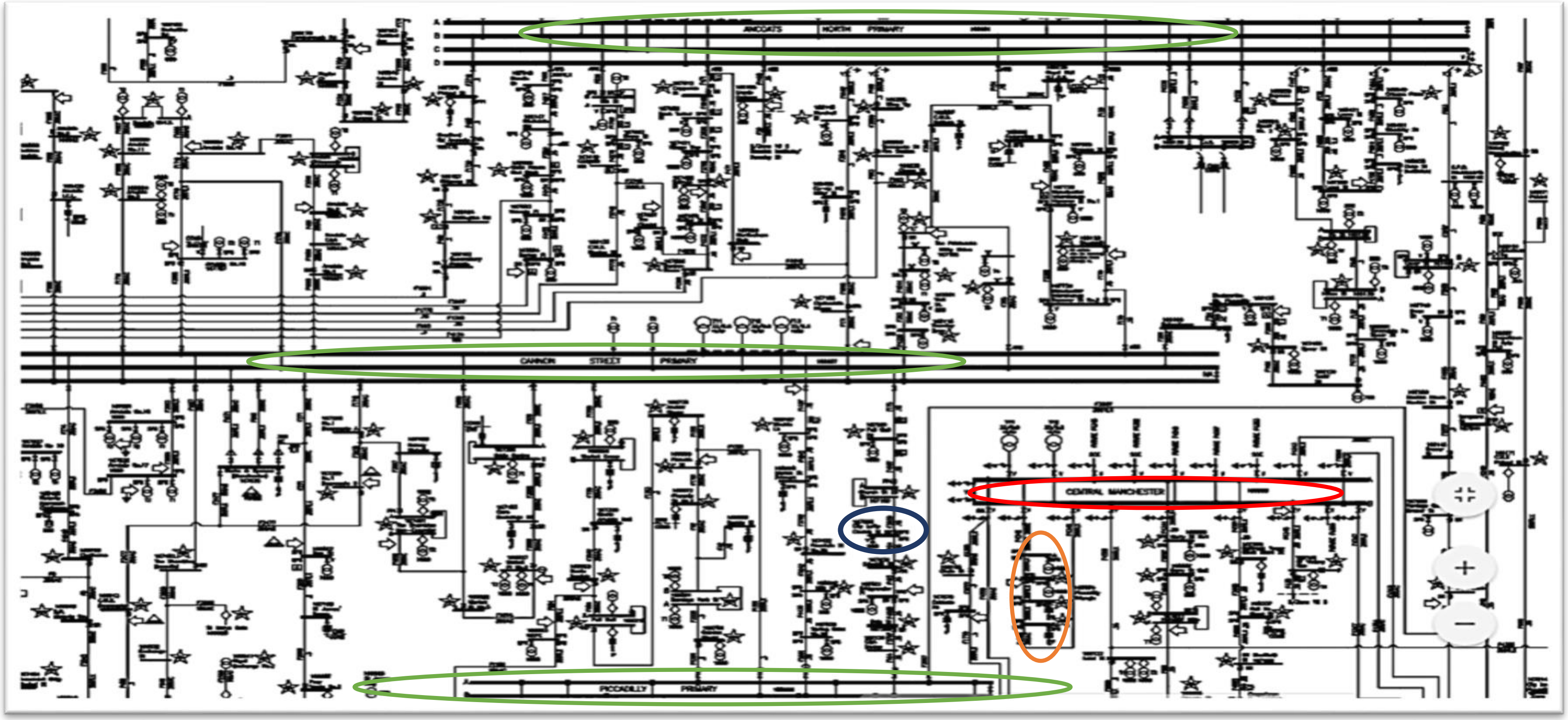

Figure 14: A section of ENW's North Manchester 6.6 – 11 kV schematic diagram (The Central Manchester Primary is shown in the red circle, the City Lofts development by the blue circle, the Piccadilly Place developments by the orange circle and the Ancoats North, Piccadilly Primary and Cannon Street Primary in green circles)

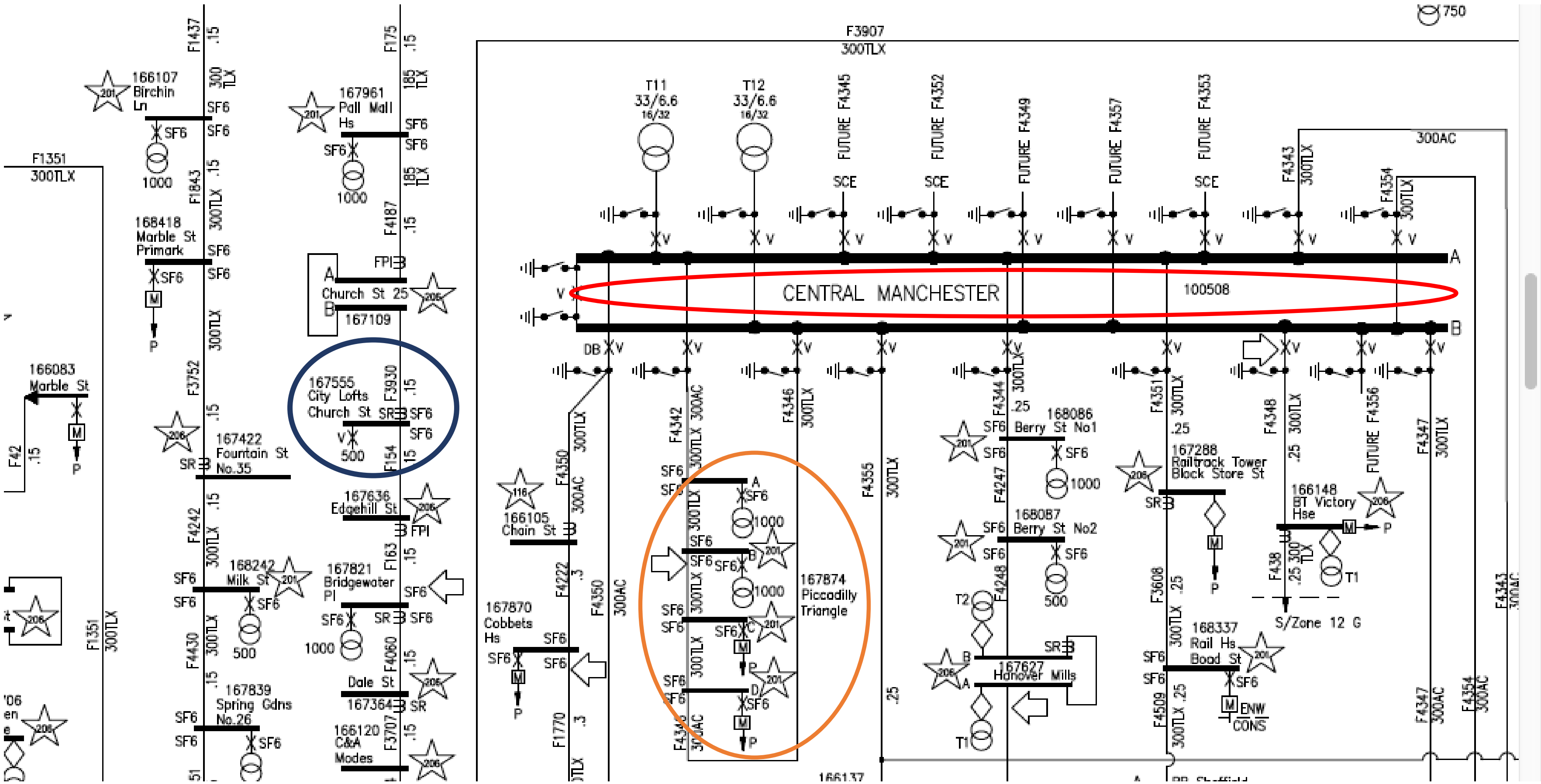

Figure 15: A magnified section of ENW’s North Manchester 6.6 – 11 kV schematic diagram (The Central Manchester Primary is circled in red, the City Lofts development in blue, and the Piccadilly Place developments in orange)

ENW's distribution network is configured to maintain supply. This means connections between different substations are built into the system. The creation of connectivity between smaller and larger substations is called 'network meshing' and is undertaken to provide and maintain network resilience (ENW, 2019a). In Chapter six, I provide more detail regarding the extended organisation of the network. Here, I simply draw attention to the links between the Central Manchester Primary (2009), the Cannon Street Primary (1972), the Ancoats North Primary (1968), and the Piccadilly Primary (1966) (Figure 14 represents these connections, with the Central Manchester Primary circled in red and the other 33 kV primaries circled in green). Figure 13 shows that the Piccadilly substation is connected to the Bloom Street BSP (1956), while the Cannon Street and Ancoats North substations are supplied by the Redbank BSP (1966).

By connecting the Central Manchester Primary to these other substations and the wider 'mini-grids'[12] they are a part of, stronger network resilience is established. If, for example, power was lost at the Central Manchester Primary, supply could be maintained in the city centre as consequence of interconnections between the Ancoats North Primary, the Cannon Street Primary and the Piccadilly Primary Substation. Accordingly, the Central Manchester Primary is not an isolated artefact, it adds to and supports a broader city centre network, making sure that electricity-demanding practices, in different buildings, such as the NQ's mixed-use City Lofts development, receive electricity on demand.

Set in the context described, the Central Manchester Primary represents a relatively rare instance of large-scale investment in the city centre's HV electricity network. It was also commissioned and built during a period when the NQ's land use change and Central Manchester's broader residentialisation and

[12] I provide more detail regarding the organisation of ENW's network as a collection of 'mini-grids' in the next chapter.

commercial development were pronounced (Chapter three and Chapter four). Studying the Central Manchester Primary's development in turn provides an opportunity to consider connections between the changing use of land and the organisation of the electricity network in the city. To draw out and make such connections, I work with 'technological frames' as an analytical concept (Orlikowski and Gash 1994; Bijker, 1995; Aibar and Bijker, 1997).

'Technological frames' and infrastructural change over time

There is a rich tradition within Science and Technology Studies (STS) of studying the 'making' of technologies and large-scale infrastructures by focusing on and conceptualising their emergence, development, stability and change over time (Hughes, 1983; Akrich, 1992; Summerton, 1992; Latour, 1996; Aibar and Bijker, 1997; Geels, 2005; Moss and Francesch-Huidobro, 2016). Different conceptual and analytical approaches have been developed to help unpack and describe the ongoing organisation of infrastructures (Hommels, 2005). The approach I draw on and mobilise concerns 'technological framing' (Orlikowski and Gash 1994; Bijker, 1995; Aibar and Bijker, 1997).

For Bijker (1995, p. 282), 'technological frames' are constructed by social actors and groups who invest 'so much in [an] artefact that its meaning… [becomes] quite fixed… [and] cannot be changed easily'. This understanding signals an awareness that 'people act on the basis of their interpretations of the world, and in doing so enact particular social realities and endow them with meaning' (Orlikowski and Gash, 1994 , p. 176). This is to say that a technology's meaning is not predetermined and that work continually goes into framing, reframing and defining a technology.

The work that goes into constructing a technological frame cannot be detached from the social realities and worlds of the actors and/or groups involved in constructing a frame (Orlikowski and Gash, 1994). The constitution of a frame thus tends to reflect and consist of the 'goals, problems, problem-solving strategies, standards, current theories, design methods… [and] testing procedures' of social actors and/or groups (Hommels, 2005, p. 331).

Additionally, processes of framing are rarely neat and uncontested, with multiple frames constructed around the 'same' technology and an 'amortisation of vested interests' occurring when no single frame is dominant (Aibar and Bijker, 1997, p. 17). As Aibar and Bijker (1997) show through their examination of the nineteenth-century Cerdà Plan, a major town planning project in Barcelona, the city's future technological design was embroiled in a contestation between two groups: engineers and architects. As opposed to one group's frame winning out, Aibar and Bijker (1997, p. 19) argue 'the city got the mobility and easy traffic attributes from the engineers' frame, while hierarchy and high density of buildings were achievements of the architects' frame'. Technological frames therefore represent social constructs, constituted through the work of social actors, which define and give a technology meaning or multiple meanings.

For the purpose of this chapter, articulating the framing of the Central Manchester Primary provides a means of unpacking, ordering and describing why the substation was needed in 2009 and how its need relates to land use change and linked 'global-local' trends, flows and intersections. Describing the framing of the Central Manchester Primary also provides an opportunity to consider what this instance of infrastructural change suggests regarding the obduracy and stability of the network. Obduracy and stability have long formed key themes within STS, with an awareness that once developed, infrastructures tend to be difficult and resistant to change (Winner, 1980; Hughes, 1983; Summerton, 1992; Coutard and Summerton, 1994; Latour, 1996; Hommels, 2005). As Hommels (2005, p. 331) explains:

> One characteristic of technology seems obvious, it is its obduracy and stability. Once the high-voltage electricity distribution system is in place, it is hardly conceivable to deconstruct it and shift to a decentralized system of windmill power generation.

The obduracy and stability of infrastructures are, in part, a product of the high sunk costs that go into making networks, which are also marked out by their 'embeddedness', 'reach and scope' (Star, 1999, p. 381). Entwined with these stubborn material attributes, exist related rules, regulations, norms and expectations, which contribute to and produce networks which tend to be resistant to change (Summerton, 1992; Summerton and Coutard, 1994; Star and Ruhleder, 1994; Star, 1999). As Summerton explains in reference to, what she terms, the 'invisible' grid:

> Multiple actors constitute… an "invisible grid" - a grid that is at least as "strong" as the physical grid. In energy systems, for example, the "invisible grid" consists of equipment suppliers, politicians on national and local levels, a multitude of regulators, interest groups, and of course all the heterogeneous customers or subscribers - from individual home owners to industries. The invisible grid often turns out to be less "malleable" than the physical one: "hard" pipelines have to bend to follow large customers, and "hard" heat or power plants perhaps have to be relocalized in response to immovable regulators. (Summerton and Coutard, 1994, p. 55)

The obduracy and stability of infrastructure networks are thus not only products of their material attributes, but also the outcome of their value-laden social organisation.

Acknowledging and building on these debates and discussion, articulating the framing of the Central Manchester Primary's development provides an opportunity to consider the obduracy and stability of the network and how such attributes are distilled and negotiated over time as part of the constitution of demand. The following empirical descriptions and my discussion of the dual framing of Central Manchester Primary thus have implications for thinking about the obduracy and stability of the network and how to conceptualise the network's change over time. These implications are unpacked in the penultimate section of this chapter.

A 'reactive' change

The Central Manchester Primary's 2009 development was discussed, during interviews with ENW employees, as a 'lumpy', 'situated' and 'calculated' reaction to and outcome of Manchester's growth and development, both in terms of the city's economic success and burgeoning population. Building on such discussions, I suggest that the Central Manchester Primary sits within a 'reactive' frame and can be seen as a response to ongoing change in the city. Specifically, when interpreted as a 'lumpy' reaction, the Central Manchester Primary's development reflects how the network is comprised of assets with real capacities, which over time are surpassed and need to be increased to support the demands of the 'city' and its related changing form and function. The idea of a 'reactive' framing is also demonstrated by more nuanced accounts of the Central Manchester Primary's situated and calculated development, which suggest an accumulation of applications for connection, on a particular part of the network, shaped and informed this instance of investment.

Bringing these points together, my account of the Central Manchester Primary's development captures how Central Manchester's ongoing land use change and the related circulation and anchoring of electricity-demanding practice bundles, hang on and over time ratchets up the material capacities of the network. The key insight here is that the network is made, at least in part, as a consequence of and in response to the ongoing flows and intersections that inform and shape the dynamics of land use change, as conceptualised and described in Chapter four. This understanding of the network's change over time is different to that offered in other works concerning infrastructural change, which tend to draw attention to and foreground the political management and organisation of particular networks (Winner, 1980; Hughes, 1983; Guy and Marvin, 1996; Graham and Marvin, 2001; Guy et al., 2001, 2010).

A ‘lumpy’ reaction

Diana, an ENW employee with over thirteen years’ experience working for the company, explained how investments in the HV network, such as the Central Manchester Primary, were ‘lumpy’ and followed broader patterns of change unfolding within the city.

> Our triggers for intervention are quite ‘lumpy’. When you reach capacity on a certain level, it is probably as important to think about what happened before the population change [in Central Manchester] around the reduction in load from more non-domestic type activities, which… freed up capacity, and you got to the point where electricity demand is growing up to a previous capacity limit and now it is increasing further. (Diana, ENW employee)

Large-scale investments in the city’s network, such as the 2009 development of the Central Manchester Primary, are, in these terms, explained as part of a broader historical transition. This transition involves a move away from the supply of electricity for industrial activity, which established a relatively healthy level of capacity, to a more fragmented pattern of demand linked with residential development in the centre of the city.

Making links between the changing use of land in Central Manchester and large investments in the electricity network, Steve, an ENW employee with over thirty years’ experience working for the company, spoke of the challenge posed by the increasing development of offices and other commercial sites within the city centre. In particular, Steve discussed the challenge posed by the spread of air conditioning units in commercial spaces:

> So, the growth of air conditioning in the city centre has really caused us issues. Whereas normally, everything with our fault management used to be the winter and then drop off in the summer, and we could also then

> do maintenance, and so on and so forth, because the load dynamic was high in the winter and low in the summer… Now, it is higher in the summer in the city centre than it is in the winter. Just because of the air conditioning. (Steve, ENW employee)

For Steve, large-scale investments in the HV network, such as the Central Manchester Primary, were part and parcel of Central Manchester's changing form and function over time, and the related spread of particularly electricity-demanding commercial practices and associated technologies.

Bringing Diana's and Steve's comments together, the Central Manchester Primary's development can be conceptualised as a 'lumpy' reaction to the city's contemporary development and transitions in its form, function and land use. Investments in the city centre network, such as the Central Manchester Primary, are furthermore usefully interpreted as 'lumpy' reactions to a breaching of historical network capacities, as a consequence of ongoing shifts in the use of the city's space, including alterations within and to practices linked with residential and commercial land uses.

A site-specific reaction to 'possible' changes

Alongside a broader 'reactive' rationale concerning the Central Manchester Primary's 2009 development, a more nuanced and site-specific explanation was expressed during interviews. This more nuanced 'reactive' framing is a product of how ENW employees discussed and explained how the company handles new applications for connection.

Alan, an ENW employee of fourteen years, explained specifically how the Central Manchester Primary was a result of a 'load' of applications for connection in a particular area of the city centre, received before the substation's commission in 2007.

> We had a load of applications… during the boom up to late 2007 and 2008. So, basically, our current network in the city centre could not cope… so we needed to invest in the network and build a primary. (Alan, ENW employee)

The applications for connection, as Alan further explained, consisted of a collection of requests, related to a number of 'smaller' developments, which reflected, what he termed, 'the fragmenting nature of… load growth' in the city centre (Alan, an ENW employee). This fragmentation was connected, by Alan, Diana and Steve (ENW employees), with numerous mixed-use residential and commercial developments, characteristic of Central Manchester's contemporary change (Seo, 2002; Hebbert, 2009). In combination, such sited developments culminated in a level of demand, which by 2007, placed the established network under a degree of 'possible' duress, resulting in a need for increased network capacity, coming in the form of the Central Manchester Primary.

My use of the word 'possible' is significant. It emphasises how the Central Manchester Primary's development represents an institutionally configured 'reaction', related to the enactment of the 'invisible' network Summerton and Coutard (1994) write about. Specifically, the possibility of breaching network capacities, leading into 2007, was a product of the load requirements and calculations submitted as part of site-specific connection applications. Such requirements are used to estimate the strain placed on the network and reflect normative values, associated with typical 'domestic' or 'non-domestic' demand and the average consumption of electricity in residential and commercial developments.

Commenting on the calculations of load submitted in applications for connection, Steve (ENW, employee) explained that it is widely acknowledged such estimates rarely materialise with the completion of a development. Diana (ENW employee) further explained that ENW understand applications for connection 'are quite over-specified'. Discussing this phenomenon, Alan explained that over-specification was a product of developers worrying about underestimating the electricity demands of buildings once complete:

> Customers [land developers] quite often put a bit of a safety net in their load… because they… never want to take [the] risk or be caught short when the building is up and running, they… much rather err on the side of caution. (Alan, ENW employee)

Crucially, such overstated requirements are used by ENW to calculate the network's ability to accommodate the load applied for. This tends to mean the network's specification is larger than the load actually placed on it. Commenting on this process of overspecification, Diana (ENW employee) made the following point:

> We [ENW] are taking connections activity and adding it on 100%. So, if they [the developer] ask for 1 MVA, then we look at what load we have got, and we add on 1 MVA. (Diana, ENW employee)

This practice and the acceptance and use of overestimated load requests was linked, by the ENW employees I interviewed, with the short turnaround period for responding to connection applications. They explained that ENW typically operates on a thirty-five-day turnaround for High Voltage (HV) connections and a twenty-five-day period for connections to the Low Voltage (LV) network. It was suggested that these timeframes leave little room for conversation regarding the load requirements outlined in applications. Instead, developers pay to reserve their requested load, and have six-months to act on successful applications.

As a consequence of the tendency of developers to err on the side of caution and overestimate load requirements, which ENW tend to accept, calculations of expected load reflect a 'possibility', as opposed to a probability that the network's capacities will be approached. Alan (ENW employee) articulated these links and this point by describing the Central Manchester Primary's development as a reaction to a 'paper problem':

> … we could see lots of applications coming in, and… there was a 'paper problem'… So, on paper, the network was overloaded, but in actual fact the network was fine. (Alan, ENW employee)

Interpreted as a response to a 'paper problem', the Central Manchester Primary's 2009 development can also be read as a situated reaction to a 'possible' problem, associated with an accumulation of applications for connection leading into 2007. These applications were related to specific instances of land use change and the anchoring of electricity-demanding bundles of practice in the city centre.

A calculated investment

A consideration of the financing of the Central Manchester Primary, reinforces the idea and framing of the substation as a situated 'reaction' to here and now demands, associated with land use change taking shape in Central Manchester in the early and mid 2000s. Alan (ENW employee) specifically explained that United Utilities (UU) (the company ENW acquired the North West's distribution network and rights from, in 2010) paid for the Central Manchester Primary in full. The company did so with the aim of recouping monies invested through a levied change, applied to new applications for connection directly supplied by and benefiting from the Central Manchester Primary.

UU footed the initial cost of investment in the Central Manchester Primary because DNO's are not legally allowed to use any of the fees paid by individual customers, through the Distribution Use of System (DUoS) fee, to finance new connections and linked forms of network extension (ENW, 2018d). As Alan explained:

> Regulators [OFGEM], some years back, deemed that it is not fair that customers should be funding new connections. So, coming back to the DUoS point, we do not get money from our DUoS income to subsidise new connections… [But] we could not charge one customer for all of the new work for the [Central Manchester] Primary. So… United Utilities funded the whole Central Manchester Primary. Utilising ECCR [*The Electricity (Connections Charges) Regulations 2002*], we then worked out… for any future connectors how much money they would owe us for utilizing or connecting of that new asset. So… we shelled out all of the money to invest in it, knowing full well other customers would be connecting of it, okay, and we had five years to recover up to the value of the initial cost of what that primary substation costs us. And we did that by working out, again crudely, the total costs of the [Central Manchester] Primary, divided by the capacity of it, which got us a pound per Kilo-volt-ampere (kVA) charge. So, any developers coming off that primary or benefiting from that primary in their quote we charged them, I think, around about, £240.00 per kVA. (Alan, ENW employee)

Building on this rationale, the 2009 development of the Central Manchester Primary represents a calculated response to the short-term and expected changing use of land in the proximity of the substation.

Working with Alan's explanation and tracing out lines of connection, represented on ENW's North Manchester 6.6 kV – 11 kV schematic diagram, proves informative in terms of identifying the types of buildings and demands involved in the calculated decision Alan spoke about (see Figure 14 and Figure 15). It is, for example, possible to link the development of the Piccadilly Place complex with the decision to invest in the Central Manchester Primary. This connection is also explicitly referred to in Mayfield Strategic Regeneration Framework, which suggests that the substation was 'built to support Piccadilly Place' (Bennetts Associates, 2009, p. 35).

The planning application for the Piccadilly Place development was logged in 2005 and granted permission in 2006 (MCC, 2006). The development was completed in 2008 (Austin-Smith: Lord, 2019). In 2005, Piccadilly Place represented 'one of the largest urban regeneration projects to be built outside London in the last 20 years' (Austin-Smith: Lord, 2019). Incorporating five buildings, Piccadilly Place is a mixed-use complex comprising: One Piccadilly Place, a 285-room hotel; Two Piccadilly Place, a 55,000 sq. ft office complex; Three and Four Piccadilly Place, which provide, in combination, 300,000 sq. ft of Grade A office space; and Five Piccadilly Place, a 167-unit apartment block (Austin-Smith: Lord, 2019). Several restaurants, a gym and commercial spaces also form parts of the development (MCC, 2006). Piccadilly Place is thus characteristic of the transition in land use experienced in Central Manchester. In turn, UU's financing of the Central Manchester Primary, which coincided with the development of the mixed-use Piccadilly Place project, supports the idea that the substation represents a calculated reaction and investment, related to land use changes discussed in Chapter three and Chapter four.

Reading the 'reactive' pieces together

Weaving the pieces discussed together, The Central Manchester Primary can be conceptualised and read as a reaction to Central Manchester's broader land use change, and as a sited and calculated response to an accumulation of applications for connection in a particular part of the city. This 'reactive' framing of the Central Manchester Primary's emergence coincides with the timing and acceleration of the NQ's commercial and residential land use change, and more broadly with Manchester city centre's development, which, as discussed in Chapter three and Chapter four, accelerated after the turn of the millennium. Framed in the terms described, this relatively rare instance of large-scale infrastructural investment in Central Manchester's HV network reflects the lumpy relationships between the use of land, the related anchoring of bundles of practice in an area, and the organisation of the electricity system over time. Key here, is the idea that the extended 'global-local' relations that shape and inform Central Manchester's land use (Chapter four) also intersect with the situated and historical capacities of the HV network in Central Manchester, reacting and culminating in moments of lumpy instances of network investment and extension.

A 'proactive' response

Complicating and challenging the 'reactive' framing, the Central Manchester Primary can also be interpreted as an outcome of longer-term expectations and visions of electricity demand in Manchester city centre and across the North West region ENW supplies. This understanding hinges on a future-orientated framing of the Central Manchester Primary, which emphasises how longer-term predictive visions and related calculations of a geography of demand affect and inform sited instances of network investment and extension.

Imagining and staying ahead of demand

The longer-term future-oriented framing of the Central Manchester Primary is captured in the substation's design. As Figure 16 shows, the Central Manchester Primary, as of November 2017, still had six 'future' circuit breaker options. These options provide additional connection opportunities. These opportunities have outlasted the five years permitted, according to ECCR legislation, for recouping monies invested in a particular asset from newly connecting customers (Department for Trade and Industry, 2002). The Central Manchester Primary's design thus clearly challenges and complicates the idea that the substation was a calculated reaction to ongoing land use change and the anchoring of electricity-demanding bundles of practices in Central Manchester in the mid-2000s.

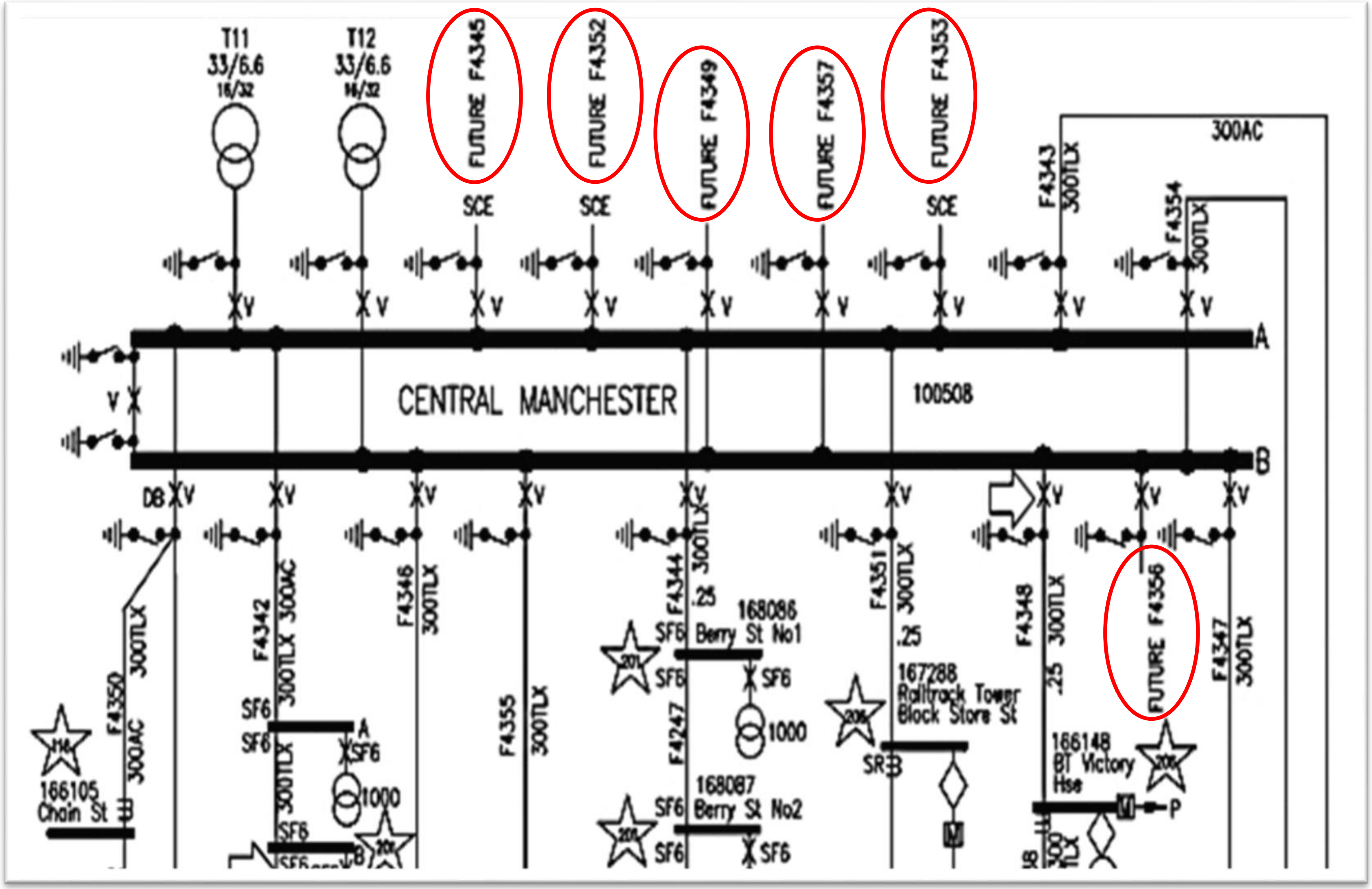

Figure 16: The Central Manchester Primary as shown on the 6.6 – 11 kV ENW schematic diagram

Diana (ENW, employee) spoke about the six ‘future’ breaker options, built into the Central Manchester Primary:

> Diana: When you get to the higher voltage stuff, the primaries, and Grid Supply Points and Bulk Supply Points… you are looking further ahead because it takes longer to intervene.
>
> Torik: Is that why on the Central Manchester Primary you have, I think, six future connection options?
>
> Diana: Yes, we have put extra spaces on the board.
>
> Torik: So, you can actually see the future scenarios?
>
> Diana: Yes…

The types of ‘scenarios’ of future electricity demand referred to and reflected in the design of the Central Manchester Primary are configured at different spatial scales and in accordance with the calculative work of other institutions, including the national government, Manchester City Council (MCC) and the Greater Manchester Combined Authority (GMCA).

On a broader North West regional scale, the future connection opportunities provided by the Central Manchester Primary fit with ENW’s (2018b, p. 2) estimation that ‘electricity demand in the region could nearly double by 2050’. This estimation connects with the ‘Central Outlook’, which is one of five calculated future scenarios concerning the trajectory of electricity demand up until 2050 across the North West (ENW, 2018b, p. 6). The other scenarios are ‘Active Economy’, ‘Green Ambition’, ‘Focus on Efficiency’ and ‘Slow Progression’ (ENW, 2018b, p. 6).

Each scenario is the product of a collection of 'differing underlying assumptions on financial and policy conditions' at a regional scale, which further reflect possible increases in the region's population and economic activity in the area (ENW, 2018b, p. 5). These assumptions are specifically linked with, for example, calculation of Gross Value Added (GVA) and population growth at a regional scale (ENW, 2018b). Entwined with these assumptions are notions of future demand and ideas about the adoption of electric vehicles (EVs) and heat pumps. Based on the 'Central Outlook' it is estimated that 'there will be up to 2.5 million electric vehicles in [the ENW] supply region by 2050… [and] up to 50% of… properties will be warmed by heat pumps by 2050' (ENW, 2018b, p. 8). These regional-wide visions also link with and reflect national political visions and policies, such as the 'Government pledge to end sales of new vehicles with conventional internal combustion engines in 2040' (ENW, 2018b, p. 8).

The links between large-scale investments in the network, the creation of additional circuit breaker options, such as those seen in the design of the Central Manchester Primary, and the crafting of future scenarios and related expectations concerning the electrification of heat and the adoption of EV's, are evident in the following interview segment:

> We all know we do not have a crystal ball. What we actually have to do is think about a plausible set of futures, fairly long-term, and against those you can then think about different decisions you would make and set up some analysis frameworks to do that… If we look ahead ten, fifteen, twenty years from now… we are expecting… load growth from electric vehicles and heat pumps. [And], the overall size of our network will become more and more important. And, if we make decisions now that are too short-term about what capacity is needed, we could have some real challenges… ahead, with a fairly rapidly increasing load growth, and it can take time to put network capacity in place. (Diana, ENW employee)

Like Diana, Karen and Malik (ENW, employees) further explained that large-scale investments in the HV network, such as the Central Manchester Primary, involved looking further ahead and calculating whether it made sense for ENW to build in spare capacity to pre-empt forecasted increases in load across the region.

Echoing his colleagues, Alan noted that part of building a strong investment case for developing the Central Manchester Primary involved answering the following types of questions:

> How much… [will an] investment… be offsetting other network reinforcement work? [And] how much will it be mitigating bad PR, in terms of ENW stifling economic development in the city centre? (Alan, ENW employee)

As Alan further explained: ‘in the case of the Central Manchester Primary, clearly the risk outweighed the cost, because it went ahead and got built’.

Drawing these points together, large-scale investments in the network, such as the Central Manchester Primary, reflect future-oriented calculations and visions, configured by and as a consequence of the work of different institutional actors and organisations. As shown, national policies connected with a broader climate change agenda, regional expectations concerning population and economic growth, and related assumptions about the uptake of electricity-demanding technologies, are combined to configure future-oriented visions of demand, which further inform the development of a network necessary to support such imaginaries.

Envisioning and staying ahead of Manchester

The ‘future’ connection opportunities built into the Central Manchester Primary do not only reflect broader national and regional visions, agendas and calculations of the economy, population and related notions of demand. The 'future' breakers shown in Figure 16 can also be linked to a set of situated and more nuanced expectations concerning Manchester city centre's future form and function, and anticipated electricity load increases in the centre of the city.

As with the broader expectation of longer-term demand growth, estimations of increasing load in Central Manchester connect with political policies and related calculations concerning the city's economic success and growing population (ENW, 2018b). In this regard, the future connection options provided by Central Manchester Primary can be associated with a commitment to supporting the aims and objectives of MCC and the GMCA, if only, as Alan (ENW employee) explained, to mitigate the bad PR of being seen to stifle the economic development of the city.

The future connection options, provided by the Central Manchester Primary, support, for example, the GMCA's aims of decarbonising transport and heating, and facilitating the delivery of ten-thousand new homes in the Greater Manchester area each year (ENW, 2018b). Drawing links between the future of the network and local authority aims, Tim (ENW employee) spoke of 'high-level conversations' between ENW and the GMCA, concerning the Greater Manchester Mayor's 'favoured approach of doing something like free EV charging in Manchester city centre'. As Tim further explained:

> Free EV charging [is]… a great idea on the face of it, you know encourage more people to use EVs and change their vehicles in town. [But] from a network angle, that causes us a real problem. (Tim, ENW employee)

Tim (ENW, employee) commented on how such aims become embroiled in investment decisions and sited instances of network extension. This connection is echoed in ENW's (2018b, p. 2) *Distribution Future Electricity Scenarios and Regional Insights* publication, within which it is stated that 'large forecast increases in demand in the Manchester area are driving the strategic development of [the] network'.

As a consequence of discussions with ENW employees and a review of company publications and diagrams, the Central Manchester Primary can thus be framed as a product of longer-term visions of electricity demand and expectations concerning the future of mobility, heating and the growth of the city. This 'proactive' framing coexists with the 'reactive' frame, reflecting how an amortisation of vested interests and values can simultaneously shape and inform a network's development (Hughes, 1983; Bijker, 1987; Aibar and Bijker, 1997).

Challenging and changing network stability and obduracy

My description of the 'reactive' and 'proactive' framing of the Central Manchester Primary show how shorter and longer-term expectations of electricity demand, connected with land use change, related visions of the region and the city, and notions of the future of mobility and heating, affect and inform the organisation, size and capacity of the electricity network in Central Manchester. Accordingly, the analysis articulated in this chapter has implications for conceptualising and thinking about how the network's stability and obduracy are challenged, and yet also reaffirmed, over time (Hommels, 2005).

A central insight of the analysis presented in this chapter is that the HV network's stability and obduracy are challenged by the 'global-local' dynamics that underpin ongoing land use change. Throughout this thesis, instances of land use change have been taken to represent the anchoring of different electricity-demanding bundles of practice, a phenomenon which has been further conceptualised, in conjunction with Massey (1991, 2005), as a consequence of multiple and intersecting 'global-local' practices and related policies, trends and events. Read in conjunction with this conceptualisation of spatial change, the

2009 development of the Central Manchester Primary Substation marks out a moment when lumpy network thresholds were approached, as a consequence of the ongoing 'global-local' spatial anchoring and layering of practice bundles and the manifestation of new and accumulating here and now demands.

The analysis presented in this chapter also shows how the established obduracy and stability of the network are affected by longer-term expectations and visions of demand, crafted simultaneously in reference to different spatial scales. As discussed, projected calculations of GVA, population growth, planned regeneration projects, and national and local authority energy policies and agendas combine and underpin the creation of visions of future demand and the network required to support such visions. This proactive work, which is captured in the design of the Central Manchester Primary, highlights a belief, on behalf of ENW employees and national, regional and city actors and planners, that electricity demand will increase. Moreover, the proactive work of such actors points to an understanding that increases in electricity demand will be spread unevenly, in geographic terms, with demand in Central Manchester pronounced and concentrated (ENW, 2018b). The obduracy and stability of the electricity network can, therefore, also be understood to be challenged and reasserted by visions, expectations and calculations related to future 'global-local' flows and intersections of investment, people and practices.

Crucially, there is more than an ongoing intersection between 'global-local' trajectories and constant change, which Massey (1991, 2005) foregrounds in her work. Instead, there are multiple material intersections between the network and more imminent and imagined changes in the use of land and related performance of practices, which justify forms of investment in hardware.

Yet, as opposed to simply representing a moment when the network's stability and obduracy were challenged by imminent and longer-term expectations of increasing demand, the Central Manchester Primary can also be interpreted as an instance of re-stabilisation. This instance of re-stabilisation saw the stability and obduracy of the network strengthened through reinforcement and increased capacity, taking shape in the form of the development of the Central Manchester Primary, which enabled and continues to enable demand to grow in the city centre.

Chapter summary and next steps

In this chapter, I have discussed the development of the 2009 Central Manchester Primary. Drawing on interview material and secondary sources, I have suggested that the substation fits within two coexisting explanatory and meaningful frames. Describing the 'reactive' framing of the Central Manchester Primary, I explained how demands, related to an accumulation of applications for connection in the mid-2000s, can be understood to have triggered this instance of network reinforcement. The ‘global-local’ flows and intersections, linked with land use change in Chapter four, can thus be usefully understood to have depended on and over time challenged the established obduracy and stability of the HV network in Central Manchester. Additionally, I introduced and articulated a 'proactive' framing of the Central Manchester Primary, which emphasises the effects of longer-term visions of electricity demand in and beyond Central Manchester. As discussed, these longer-term future-oriented expectations are captured in the substation's design and can also be understood to challenge the stability and material status-quo of the HV network, bolstering the rationale to invest in and develop the Central Manchester Primary. The city’s network thus appears to extend and grow as a consequence of imminent and imagined demands, the latter of which arguably become more likely to materialise as a consequence of the network's extension.

The Central Manchester Primary is, however, also part of the wider electricity system. Acknowledging this fact raises three further questions:

- How does investment in specific network assets, such as the Central Manchester 33 kV Primary, relate to the management of the electricity system at different spatial scales?

- How does Central Manchester's land use change relate to and depend on the wider organisation and management of the network that supplies electricity?

- What does studying the organisation of the hardware that supplies electricity to Central Manchester, at different scales, reveal about the constitution of electricity demand?

These questions form the focus of Chapter six.

Chapter six: The organisation(s) of electricity system(s)

Introduction

The Central Manchester 33 kV Primary is part of a geographically stretched material network, which is organised and maintained by multiple organisations. This geographically dispersed socio-material network also supplies the Northern Quarter (NQ) and Central Manchester. Acknowledging these two points, in this chapter, I explore: how Central Manchester's land use change relates to and depends on the wider organisation and management of the network that supplies electricity; and, how specific network investments, such as the Central Manchester 33 kV Primary, relate to the management of the electricity system at different spatial scales. I also consider what studying the organisation of the hardware that supplies electricity to Central Manchester, at different scales, reveals about the constitution of electricity demand.

My analysis in this chapter draws on documentary evidence, including twenty-eight energy and system-orientated reports and strategy publications (see Appendix 3). I also work with a number of spreadsheets, datasets and maps. All of the sources worked with are produced by either Manchester City Council (MCC), the Association of Greater Manchester Authorities[13] (AGMA), the Greater Manchester Combined Authority (GMCA), Electricity North West (ENW), National Grid (NG), National Grid Electricity transmission (NGET) or the European Network of Transmission System Operators for Electricity (ENTSO-E). These and other organisations comprise parts of the 'invisible grid' of multiple

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[13] The Association of Greater Manchester Authorities (AGMA) was established in 1986 and formed a local government association comprised of ten local authorities, including MCC. However, the formation of the Greater Manchester Combined Authority (GMCA) – 'the country's first statutory 'supercouncil' with power to co-ordinate the region's regeneration, economy and transport priorities'– saw the AGMA's function significantly reduced (Manchester Evening News, 2019). GMCA now takes responsibility for crafting energy strategies for the Greater Manchester region.

actors, stakeholders and suppliers, which have various agendas, goals and objectives (Summerton and Coutard, 1994, p. 55).

Using and working with different examples and representations, connected with the organisations listed, I discern and describe the constitution of three ‘professional worldviews’ and versions of the electricity system (Ellis, 1996). Following Ellis (1996, p. 264), each professional worldview is understood to represent a discursive and structuring formation, linked to a professional organisation and their aims, objectives and ways of defining challenges.

The first view I articulate and describe concerns the constitution of a Manchester-city-centric version of the electricity system, which is represented in and largely the product of the work of MCC, the AGMA, the GMCA and ENW. I specifically determine this view through an analysis of twelve energy strategies, authored or published by MCC, the AGMA or the GMCA, between 2005 and 2017 (Appendix 3). The Manchester-city-centric view of the electricity system is part of a wider political landscape, within which city authorities have taken a greater interest in the generation, consumption and management of energy in order to tackle climate change (Betsill and Bulkeley, 2006; Rosenzweig, 2010; Bulkeley, 2014; Carter et al., 2015; Webb et al., 2016; C40, 2019; Core Cities, 2019). I also show that the constitution of a Manchester-city-centric view of the electricity system does not only exist in a discursive form. Indeed, I link the production of a Manchester-city-centric view of the electricity system to the constitution of an urban version of the electricity network. I articulate this point by drawing connections between the aims and objectives of relevant city authorities and ENW’s work and investment in the distribution network that supplies the city.

The second view I describe is a product of studying how ENW and other organisations, involved in the ongoing management and regulation of regional distribution networks, represent their work. This view involves a foregrounding of the mechanics of distribution. Specifically, I describe how ENW represents its work as largely ordered around the ongoing maintenance, repair and investment in a collection of 'mini-grids'. In this instance, the dynamics that mark out the Manchester-city-centric version of the system, such as the effects of local political aims and objectives on the organisation of infrastructure, are backgrounded. Instead, instances of investment in the network that supplies electricity to Central Manchester appear to be the outcome of the approach employed by ENW as part of the company's ongoing management of a material and bulky regional distribution network. From this point of view, the constitution of electricity demand in Central Manchester depends on the hardware-oriented management of a regional distribution network, which appears to have little to do with Central Manchester and more to do with standardised practices of maintenance and investment.

The third professional view of the electricity system I discern and describe is an outcome of studying how NG, NGET and the ENTSO-E represent their work and rationalise investments. Focusing on the discursive work of these organisations, I suggest an international view and version of the electricity system is configured. This view and version is premised on facilitating the transnational and marketized exchange of electricity. Again, Manchester and other cities are of little relevance in reference to the constitution of an international view and version of the electricity system.

Read together, my description of three different views and versions of the electricity system suggest that the relationships between land use change in Central Manchester and the hardware that supplies electricity are not clear cut or easy to explain in causal terms. This is because local and situated changes in electricity demand depend on and affect the ongoing and distributed organisation of hardware according to different organisational rationales, which are configured at various spatial scales. This understanding renders electricity demand a sited and extended spatial phenomenon and problematises the idea that electricity consumption and demand belong to the city and are the responsibility of city authorities (C40, 2019; Core Cities, 2019). My analysis in this chapter also suggests that the 'same' instance of infrastructural investment, such as the development of the Central Manchester 33 kV Primary, can be simultaneously interpreted as a product of different organisational rationales and logics. My analysis, in turn, has implications for conceptualising and explaining how electricity networks change over time. In particular, my analysis problematises accounts that suggest electricity networks are largely the outcome of either urban, regional or national relations (Hughes, 1983; Frost, 1993; Graham and Marvin, 2001; Verbong and Geels, 2005; Harrison, 2013; Amin, 2014; Moss and Francesch-Huidobro, 2016; Olufolahan et al., 2018). Bringing these points together, this chapter reveals how the constitution of electricity demand and the relationships between practices and electricity infrastructure, in and beyond Central Manchester, produce, relate to and depend on the enactment of multiple views and versions of the electricity system.

Professional worldviews

The three views of the electricity system I describe represent different professional worldviews of the infrastructure that supplies electricity to Central Manchester (Ellis, 1996). My use of 'professional worldviews' follows Ellis' (1996, p. 264) conceptualisation and study of the development of urban freeways in America between 1930 and 1970. Ellis (1996) argued that the constitution of urban freeways took shape at the intersections between different professional groups, their every day and codified practices, and related ways of working and representing their work. As he explains:

> Urban freeways were designed and built primarily by highway engineers, but city planners, landscape architects, and architects took part in the debates over freeway design. The involved professionals used different ideas and images to advance their goals: intellectual tools acquired through education, professional socialisation, and daily practice.

> Professional worldviews shaped the styles of research, the generation of alternatives, and the presentation of proposals to the wider public. (Ellis, 1996, p. 265)

Like Bijker's (1995) conceptualisation of technological frames, Ellis (1996) conceptualises professional worldviews as meaningful and constitutive constructs. However, while technological frames can be constructed by various social actors and groups, Ellis (1996) emphasises how professional worldviews are connected with the long-term discursive formation of a profession, as a body of knowledge, which guides and informs action and the constitution and resolution of challenges. As he notes:

> Although professions harbour diverse individuals, typical approaches to problem solving congeal into standardised practice. In order to enhance their legitimacy, professions project auras of scientific rigour, nuts-and-bolts competence, or, in design fields, of aesthetic subtlety, intellectual complexity, and professional panache. (Ellis, 1996, p. 265)

Key here, is the idea that professional worldviews form 'sets of values with respect to the relationship between technology and work' (Star and Ruhleder, 1994, p. 263). In this respect, the constitution of different worldviews and their constitutive effects are linked with professional bundles of codified practices and related rules, tools and representations.

Professional worldviews are, moreover, often associated with responsibilities configured in reference to different spatial scales. As Ellis (1996, p. 263) explains, in relation to his empirical case study:

> The fundamental principles that would guide freeway planning doctrines were forged by highway engineers during the 1930s and 1940s and were codified thereafter. Strongly influenced by an engineering worldview and by the rural and suburban location of most highway construction, these

> ideas broke down in the inner cities, where strikingly different spatial and social conditions prevailed.

Taking inspiration from Ellis (1996), in what follows, I describe three professional worldviews, which have spatial dimensions and are connected with the work of organisations that take an interest in and/or are directly involved in the ordering of hardware that supplies electricity to Central Manchester. As will become clear, each view has consequences for understanding how electricity demand is facilitated and further implications for thinking about and conceptualising how and why the electricity system develops and changes over time.

A Manchester-city-centric view of the electricity system

In this section, I discuss the production of a Manchester-city-centric view of the electricity system, which I connect with the work of and relationships between Manchester City Council (MCC), the Association of Greater Manchester Authorities (AGMA), the Greater Manchester Combined Authority (GMCA) and Electricity North West (ENW). The representation of this view of the system is predominately articulated in a series of MCC, AGMA and GMCA energy strategies and policies, of which I have reviewed twelve, dating from 2005 to 2017. These publications were selected because they represent a collection of work directly concerned with the city's energy consumption and generation (Appendix 3). I suggest the Manchester-city-centric view of the electricity system not only takes shape on the pages of city-specific energy strategies and publications but is enacted through the implementation of policies and through the relationships between the MCC, AGMA, GMCA and ENW.

The constitution of a Manchester-city-centric view and version of the system fits with a corpus of literature concerning urban infrastructure (Guy et al., 1997, 2001, 2010; Graham and Marvin, 2001; Coutard et al., 2004; Moss, 2008; Monstadt, 2009; Hodson and Marvin, 2010, 2012; Graham and McFarlane, 2015). Within this tradition, strong connections are made between the political, economic and social landscapes of cities and the organisation of service networks to the effect that infrastructures are generally framed as urban phenomenon. Demonstrating this tendency, Monstadt (2009, p. 1924) argues that the 'formation of… infrastructure problems and the development of sociotechnical innovations… are geographically concentrated on the terrain of the urban and are vitally shaped by urban processes'.

Making a Manchester-city-centric view of the electricity system

Since the publication of the 'first immediate example' of a Manchester energy strategy, in 2005, progressively detailed, precise and prescriptive strategies have been written (MCC, 2005, p. 4). The following documents are particularly pertinent in this regard: *Decentralized and Zero Carbon Energy Planning* (AGMA et al., 2010)*; Greater Manchester Spatial Energy Plan: Evidence Based Study* [14] (Energy Technologies Institute, 2016); *Climate Change and Low Emissions Strategies' Whole Place Implementation Plan for Greater Manchester* (GMCA, 2016); *Manchester Climate Change Strategy 2017-50* (Manchester Climate Change Agency[15] (MCCA), 2016). In each of these publications, detailed accounts and representations of the organisation of electricity generation, provision and use are articulated in reference to the Manchester local authority region and/or the Greater Manchester region.

Figure 17, for example, provides a representation of the organisation of utility suppliers in the Greater Manchester region in 1938, and is used in the AGMA et al. (2010) publication to open up a discussion about the organisation of the city

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[14] Although authored by the Energy Technologies Institute, this publication is a product of collaborative work with the Greater Manchester Combined Authority (GMCA).
[15] The Manchester Climate Change Agency (MCCA) is a community interest group which, since 2009, has been responsible for developing a city-oriented response to climate change on behalf of MCC (MCCA, 2019).

region’s energy systems. Figure 18 and Figure 19 are instead representations taken from the *Greater Manchester Spatial Energy Plan: Evidence Based Study* (Energy Technologies Institute, 2016). Figure 18 specifically represents the organisation of the distribution network that underwrites the GMCA region by cutting it away from a broader infrastructural geography of generation and transmission (Energy Technologies Institute, 2016, p. 79). Likewise, Figure 19 depicts the load capacities of 33 kV substations in the GMCA region as disconnected nodes, anchored in and defined by a local political geography (Energy Technologies Institute, 2016, p. 80).

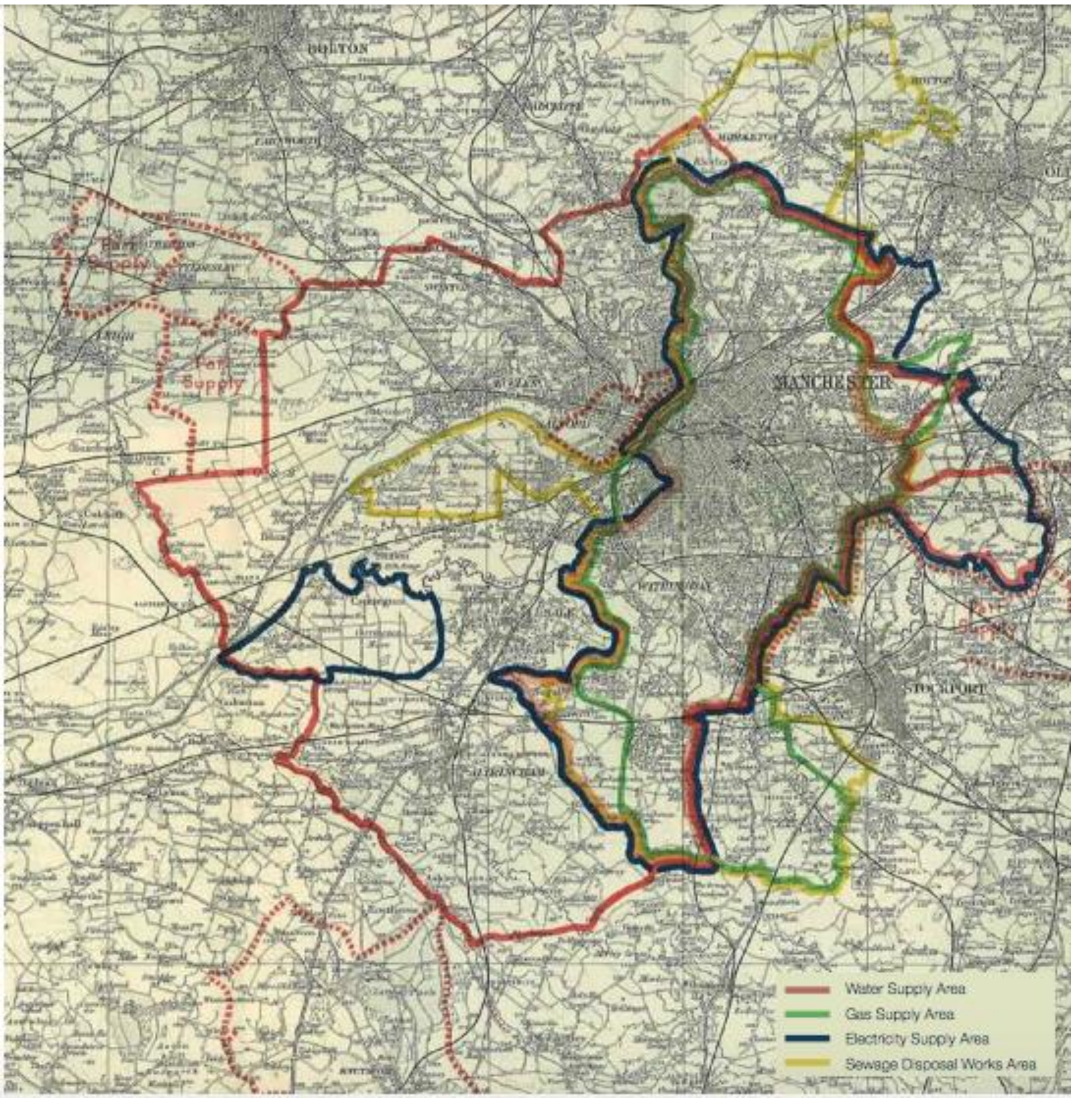

Figure 17: Manchester Corporation’s gas, electricity, water and sewerage undertakings in 1938 (AGMA et al., 2010, p. 7)

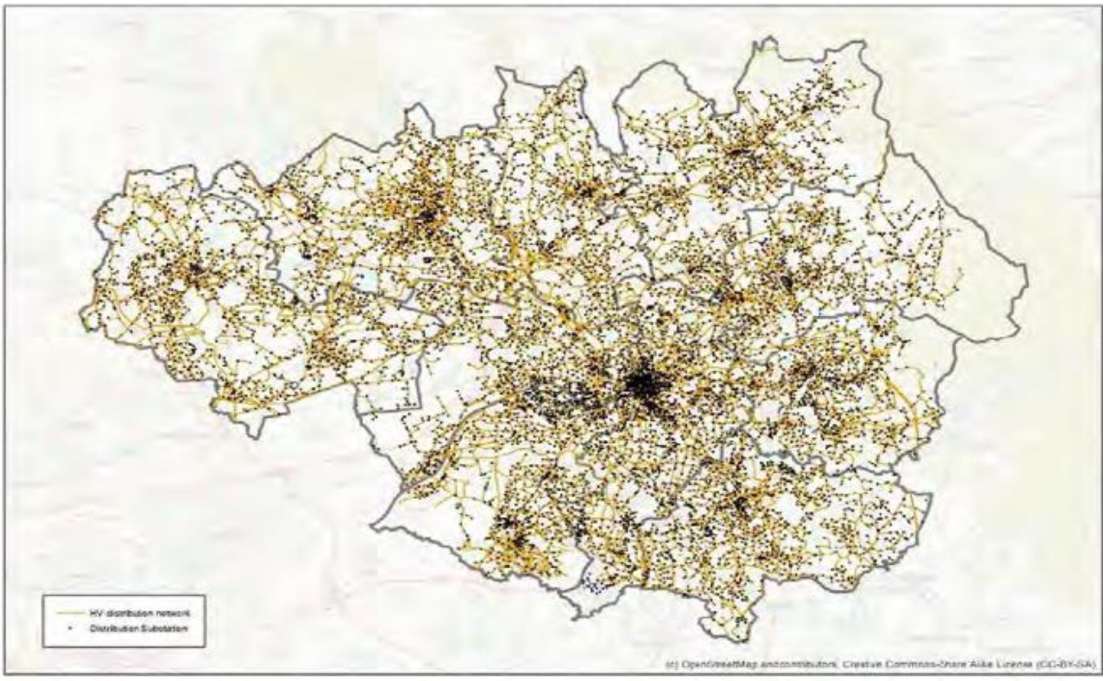

Figure 18: Representation of Greater Manchester's HV distribution network and distribution substations (Energy Technologies Institute, 2016, p. 79)

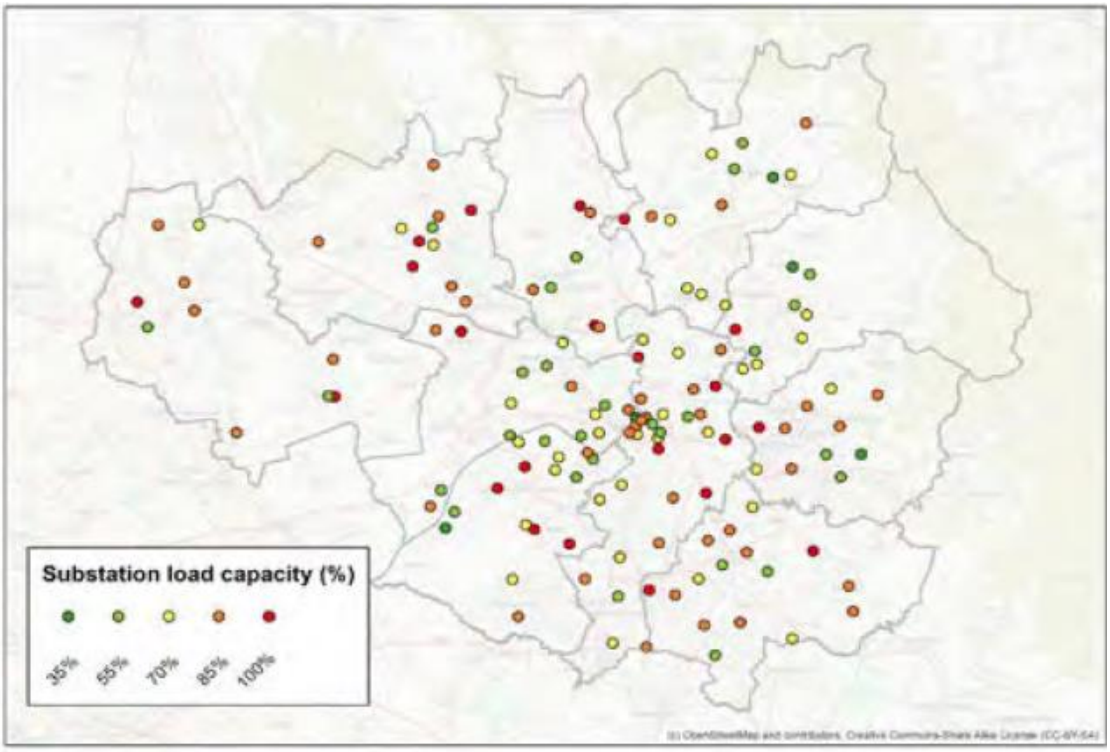

Figure 19: 33 kV substation load capacities in Greater Manchester region (Energy Technologies Institute, 2016, p. 80)

Together Figures 17, 18 and 19 equally focus on and reinforce the notion that the electricity system that supplies Greater Manchester belongs to the city region and that it is the concern of relevant local authorities. This abstracted and politically bounded view of the system sees the electricity infrastructure that supplies the city region as an entity in and of its own right, having been disconnected from a broader and geographically dispersed set of material and institutional connections.

The political bounding of the city region's infrastructure is also evident in a series of city authority policies, aims and strategies, which further help shape and constitute a Manchester-city-centric view and version of the electricity system. A key example of this is provided in the MCCA (2016, p. 29) publication, *Manchester Climate Change Strategy 2017-50*, within which the following longer-term aim is outlined:

> By taking much greater influence, control and ownership of the city's energy system, the city's residents and businesses will be supplied with 100% clean energy by 2050. This will include renewable electricity generated within Manchester, and renewable electricity generated outside our boundaries and imported into the city via a local energy company, or similar organization(s).

Although signalling an awareness that the city's current network exists beyond the bounds of the city and the local authority's jurisdiction, this aim nevertheless frames Manchester's energy system as belonging to the city and its local political institutions.

Similar statements of intent and policies concerning the constitution of a Manchester-city-centric view of the electricity system are articulated in other publications. In the GMCA (2016) *Climate Change and Low Emission Strategies' Whole Place Implementation Plan for Greater Manchester 2016-2020* these take the form of specific proposals concerning the organisation of the city region's energy generation and consumption. Figure 20 represents a selection of these proposals, which link directly with the generation, distribution and consumption of electricity (GMCA, 2016, p. 11).

Theme	Action	Led by:	Resources	Impact (tCO_2)
Cross Cutting	M1: Consider how best to use spatial plans and related levers in order to achieve compliance with GM's current and 2020+ low carbon aspirations, and advocate increasing well-connected, dense urban development.	GMCA PHE Teams	GMCA revenue	Long: 1 million
Energy	M2: Undertake detailed master-planning and design a long term energy infrastructure plan and map for Greater Manchester through the Energy System Catapult's Smart Systems and Heat Programme.	GMCA Env Team, DBEIS, ESC	ETi/GMCA Funding	Long: 1 million
	M3: Deliver a large-scale demonstrator of smart heat systems within Greater Manchester to test and explore the viability of the Masterplan.	GMCA ESC DBEIS	DBEIS, ERDF	5,000 (Est.)
	M4: Deliver current pilot of heat pump installation in social homes, supporting tenants with the change, and extend pilot to deploy a wider demonstration of integrated heat pumps, heat networks and demand aggregation in domestic dwellings to provide a financially viable offer to private landlords and owners.	GMCA Env Team, NEDO, Hitachi, & landlords	NEDO, DBEIS, Hitachi, ALMOs	3,600
	M5: Deliver existing PV projects and establish a pipeline of local authority-lead photovoltaic installations.	LAs and LCPDU	Cap Ex Inv Fund	206,900
	M6: Complete Local Authority lead onshore wind assessments and deliver a programme of onshore wind investments. Identify and progress alternative electricity generation including biomass, hydro etc.	LAs, Peel & GMCA	Cap Ex, Inv Fund	102,400
	M7: Deliver a programme of identified local energy efficient heat networks and plan for their longer term integration.	LAs, LCPDU	ERDF Inv Fund, Cap ex, ELENA,	177,500
	M8: Review existing research, assess the potential for and continue to promote deployment of alternative small, mid and commercial heat energy across GM. If viable, develop appropriate schemes.	LCPDU, Local Authorities	Cap Ex, Inv Fund	339,400
	M9: Replace Greater Manchester's street lighting and signals with smart LED systems.	LAs LCPDU, TfGM	ELENA, Salix	117,600
	M10: Deploy a smart distribution system (DMS) with dedicated communication network for the whole ENW network by 2018 and deliver a £50 million programme of smart network changes and integrated storage pilots to promote connection of decentralised energy, and deploy smart meters for gas and electricity.	ENWL, Schneider GMCA, MCC, Carbon Co-op, retailers	Private Sector ENWL, OFGEM, EU Horizon	495,500
	M11: Expand and extend community energy partnership initiatives across the whole of Greater Manchester.	GMCA – Oldham MBC	DBEIS, GMCA capacity	Enabling
	M12: Develop alternatives to existing energy systems, including hydrogen and other storage initiatives.	GMCA, Universities, Viridor	EU Funds and UK Research	Enabling
	M13: Seek to identify and accelerate energy generation schemes that the private sector and community groups could bring forward.	GMCA Env Team	GMCA, DBEIS	Enabling

Figure 20: GMCA (2016, p. 11) action plan for the Greater Manchester energy system

Each proposal in the GMCA (2016) publication differs in scale and scope. Action M2, for example, outlines the aim of developing an 'energy infrastructure plan and map', which will be used to inform the development of a smart and electricity dependent city heating network (likewise, M3, M4, M7 and M10 also concern the reorganisation of heating in the city). The concern with constituting a smart heating network links with Action M10 and the GMCA aim to quicken decarbonisation across the city region by 2050, by supporting the development of a smart distribution system for electricity. This goal is aligned with wider international targets (UN, 2015). It is proposed that the smartification of the distribution system will make it easier to connect and manage embedded forms of renewable generation, whilst also supporting the increased adoption of electric vehicles (EV) and aiding the ongoing electrification of heat (GMCA, 2016). Read together, such proposals and the broader GMCA (2016) plan represent the work undertaken to bring about, shape and inform the city region's electricity system.

The production of a Manchester-city-centric view of the system is further evident in and manifest through the GMCA's support and funding of the Greater Manchester Electric Vehicle charging network. The 'Greater Manchester Electric Vehicle network is… one of the biggest and most modern in the UK, with 318 charging points' (Transport for Greater Manchester (TfGM), 2018). Figure 21 represents the locations of the current arrangement of charging points on the network (TfGM, 2019).

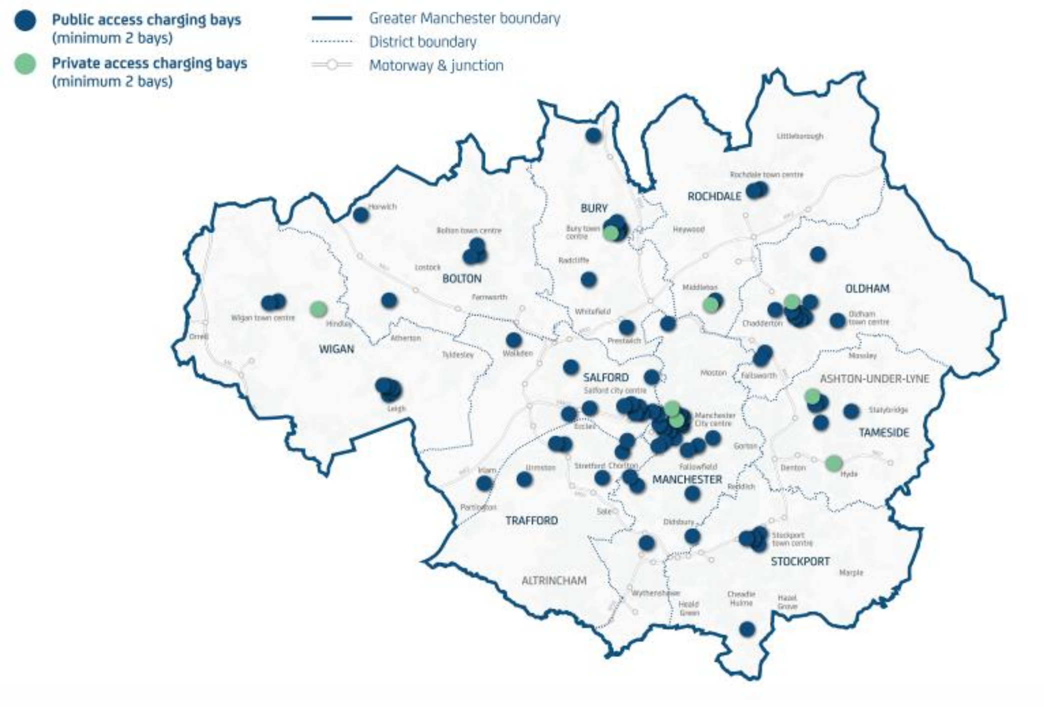

Figure 21: Greater Manchester Electric Vehicle network (TfGM, 2019)

The extension of this electric vehicle supportive infrastructure is a key part of the Greater Manchester Mayor’s plan to make Greater Manchester one of the leading green cities in Europe (MCCA, 2018). In support of this green city agenda, a further £3 million were committed to extending EV infrastructure across the city region in March 2018 (TfGM, 2018).

As outlined in a range of company publications and as discussed in Chapter five of this thesis, the uptake of EVs poses a major challenge for ENW (2017a, 2017b, 2017c, 2017d, 2018b, 2018c). This is because the local authority’s supported development of the Greater Manchester Electric Vehicle network depends on and will continue to involve the extension of the distribution network ENW owns and manages. The work of the GMCA, in this instance, specifically hangs on and informs the ordering and management of electricity hardware, including the creation of charging points and the provision of sufficient capacity.

My analysis in the previous chapter is also salient in terms of emphasising the relationships between the work of local city authorities and the ordering of ENW's distribution network. As discussed, local authority plans, policies and projections, including GVA estimations and population forecasts, inform investment decisions. Chappells' (2003) work, which shows how specific urban regeneration projects in Manchester affect and shape the management of the distribution network, draws attention to very similar connections.

Read in conjunction, the points raised in this section emphasise the production of a Manchester-city-centric view and version of the electricity system. This view of the electricity system hinges on a process of abstraction, whereby the networked hardware that supplies electricity to Manchester and/or the Greater Manchester region is cut away from wider material and institutional geographies. This process of abstraction is defined by the institutional and spatial remit of local authorities and echoed in policies, aims, objectives and maps concerning the current and future ordering of electricity infrastructure. These aims, policies and maps further contribute to a view of the city's 'needs' and reflect calculations and expectations of Manchester's future form, function and electricity demand. Such aims, policies and expectations also shape investment in electricity hardware.

ENW's regional view of the electricity system

Although I connected ENW with the production of Manchester-city-centric view and version of the electricity system, those with whom I spoke at ENW took a more regional view of the electricity network, and the systems and technologies of which it is made. This view is further represented across a range of ENW publications, maps and schematic diagrams and is captured in the work of the other thirteen Distribution Network Operators (DNO) that operate in the UK and are members of the Energy Networks Association (ENA) (ENA, 2018; OFGEM, 2018).

My description of the constitution of a hardware-oriented and regional view of the electricity system casts the constitution of electricity demand in Central Manchester (linked with land use change) in a broader organisational and infrastructural geography connected with the mechanics of distribution. Based on this view, investments in assets, such as the Central Manchester 33 kV Primary, also appear to be part of the ongoing organisation of a regional network, with changing patterns of electricity consumption and demand configured and managed at a regional scale. With the regional mechanics of distribution foregrounded, the politics of the city and related administrative ambitions are backgrounded.

I articulate an account of this regional view of the electricity system by first describing the organisation of ENW's distribution network. I subsequently explain how the company represents its management of this network.

ENW's regional distribution network

ENW owns, operates and manages £12 billion worth of assets, including 56,000 km of network, sixty-six 132 kV bulk supply points (BSP), 363 33 kV primary substations and 33,000 transformers (ENW, 2018a). The company's network serves approximately two and a half million premises and five million customers across the North West region[16] (Figure 22) (ENW, 2017a, 2017b).

[16] The North West region ENW operates across does not match the boundary of the North West region of England. ENW's boundary is, instead, connected with the brake-up of the electricity distribution network into fourteen different networks (OFGEM, 2018).

Figure 22: Map of the geographical area ENW operates across (2017b, p. 4)

As explained in Chapter five, ENW's infrastructure has a somewhat flexible topology, as it is built to offer security and bolster resilience through interconnection between different assets. Interconnection enables electricity to flow to the same destination via a variety of routes. The constitution of network resilience through interconnection acknowledged, it is still possible to describe how ENW's network is designed to work in a business-as-usual scenario.

ENW takes over responsibility for distribution at 132 kV and below from the National Grid and does so within a defined geographical area (Figure 22). ENW's distribution network is fed by nineteen Grid Supply Points (GSP) that are owned and operated by National Grid (NG) (ENW, 2018a; NG, 2018b). GSPs connect to Bulk Supply Points (BSP). Typically, at a BSP, electricity is transferred down to 132 kV before feeding through to an assortment of ENW owned and operated 33 kV primary substations, where power is generally stepped down to 6.6 or 11 kV. Electricity tends to be transferred down once more and distributed to various customers. Following this pattern of design, it is possible to trace out the wider connections that underpin ENW's distribution of electricity to Central Manchester.

Within Central Manchester there are currently seven 33 kV primary substations[17]. These are marked on Figure 23 by a plug icon. Besides any planned or unplanned maintenance works, which see a rerouting of electricity, three different BSPs feed subsets of the seven 33 kV primaries located in the centre of the city. Of the seven 33 kV primaries in the city centre, five (shown in blue on Figure 23) are fed by the Bloom Street BSP, two (shown in yellow) by the Red Bank BSP, and one (the Central Manchester Primary, which is shown in mauve) by the Stuart Street BSP. Figure 24, which provides a representation of extended connections, shows that the Bloom Street BSP is fed by the South Manchester GSP, the Red Bank BSP by the Whitegate GSP, and the Stuart Street BSP by the Stalybridge GSP.

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[17] Central Manchester is taken to form the area inside the major ring road that surrounds the centre of the city (Marketing Manchester, 2018). The most southernly Ardwick 33 kV Primary, represented by a plug icon and shown in mauve on Figure 23, is not in the city centre. Neither is the Ancoats North 33 kV Primary, which is represented by the yellow plug icon in the north-east of the map on Figure 23).

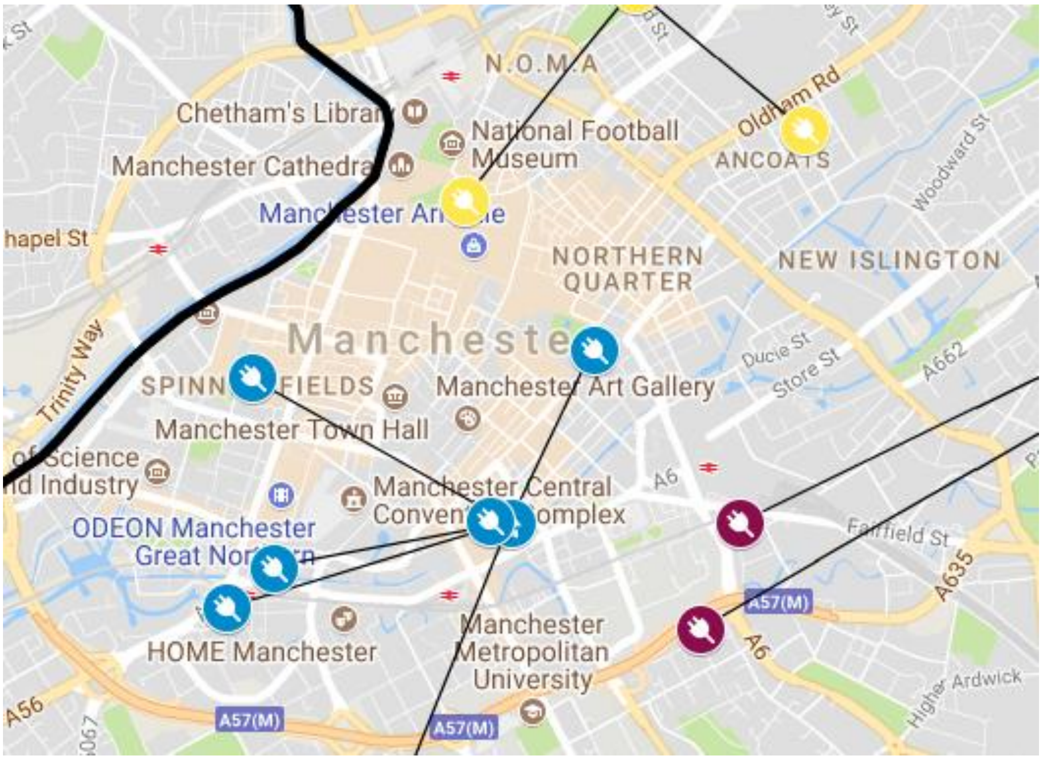

Figure 23: 33 kV primary substations in Central Manchester

Figure 24: Depiction of the three grids that feed primary substations in Central Manchester

Figures 23, 24 and 25 represent how ENW’s network is organised as a series of ‘mini-grids’. A ‘mini-grid’ consists of a BSP, which feeds a number of 33 kV primary substations . Figure 25 represents nine such grids and the flow diagram, represented by Figure 26, provides a depiction of the Stuart Street ‘mini-grid’ and wider connections. This ‘mini-grid’ feeds seven 33 kV substations, including the Central Manchester Primary. Each ‘mini-grid’ is connected to a GSP (ENW, 2018a). The Stuart Street ‘mini-grid’ is, for example, connected to the Stalybridge GSP, a 275 kV substation which feeds a total of six ‘mini-grids’. As noted, each GSP is owned and maintained by National Grid (NG, 2018b). For this reason, GSPs hold the peculiar position of feeding ENW’s ‘mini-grids’, whilst not forming a part of the ‘regional’ distribution network which the company manages and maintains.

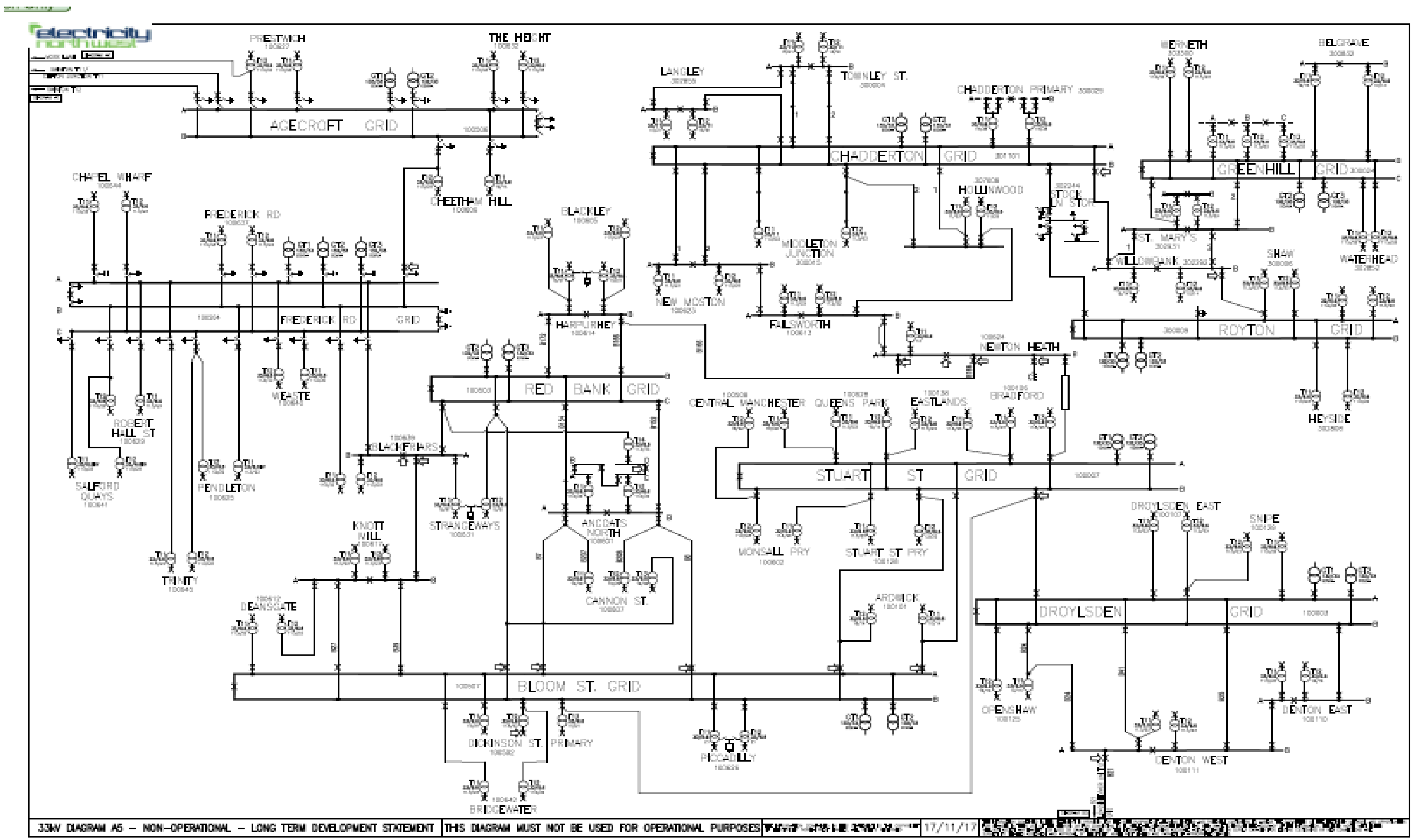

Figure 25: ENW schematic diagram of 132 kV and 33 kV substations in North Manchester

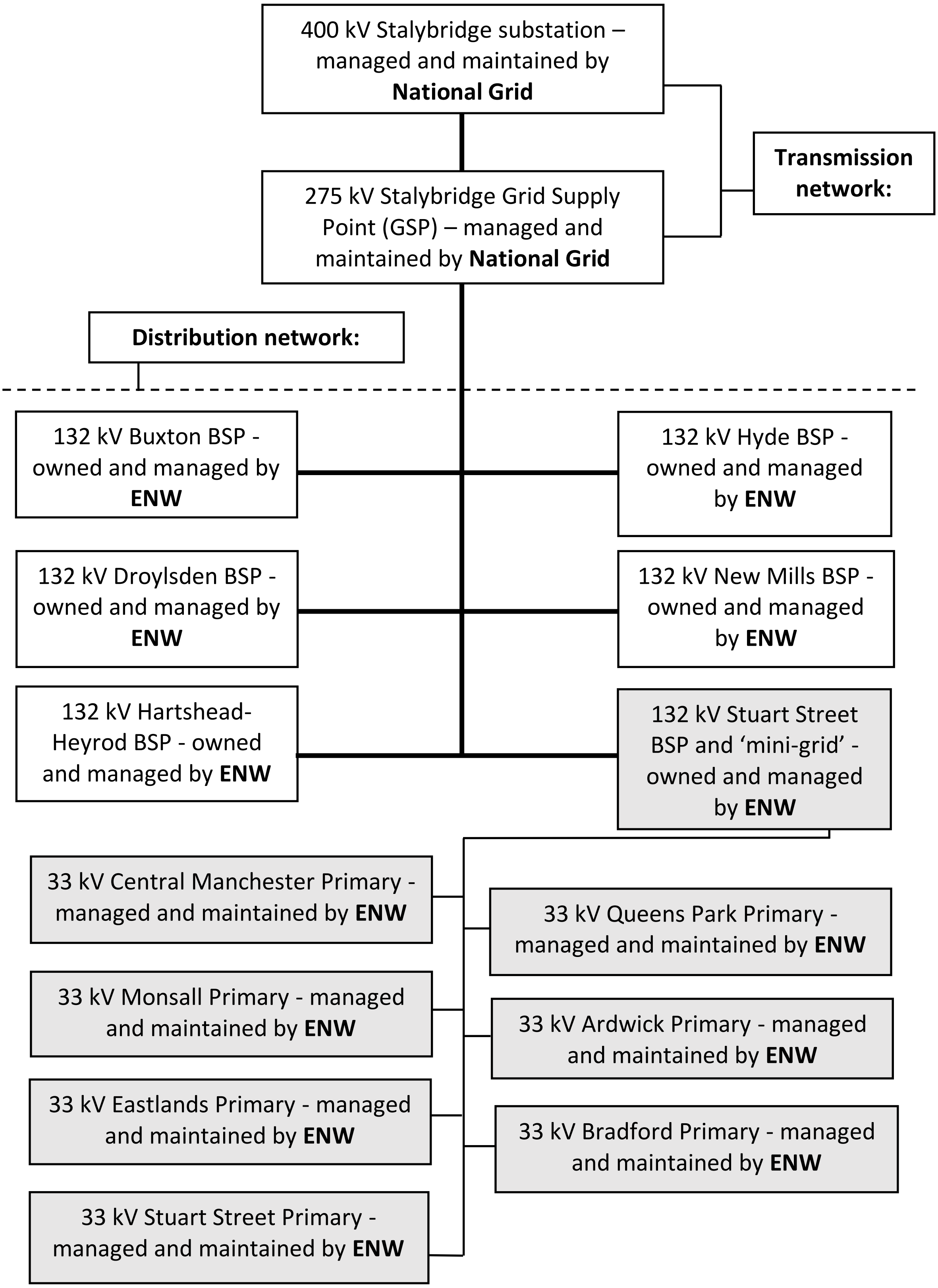

Figure 26: Flow diagram depicting the organisation of the Stuart Street 'mini-grid' and wider connections

Managing and investing in a system of 'mini-grids'

The 'mini-grid' organisation of ENW's network is not only a neat means of interpreting and representing the ordering of hardware that the organisation manages and maintains. The ongoing management and organisation of 'mini-grids' represent a central means by which ENW structures and frames its operations and investments in hardware. The regional 'mini-grid' orientation of ENW's work is stressed in a number of publications, which describe and emphasis the dispersed material geographies of 'mini-grids', as opposed to the demands of specific sites, such as the Northern Quarter (NQ) or Central Manchester (ENW, 2017c, 2017d, ENW, 2018b).

The 'mini-grid' orientation of ENW's work is, for example, represented in the organisation's *Long Term Development Statement* (ENW, 2017d). This publication provides detail regarding 'discretionary capital investment proposals that have received internal financial approval and proposals related to customer connections where a connection offer has been accepted' (ENW, 2017d, p. 20). Each proposal presented in the statement is discussed in reference to the 'mini-grid' it concerns.

Figure 27 represents an example of proposals outlined in 2017 (ENW, 2017d). As shown on Figure 27, the GSP related to each proposed investment is noted first, then, in the 'Area of the network affected' column, the particular HV asset that the proposed intervention refers to. The detail provided under this column concerns the number of customers the asset supplies. This detail underlines the affordances of the asset, as opposed to the distributed nuances of demand in relation to particular places, such as the NQ. Likewise, in the 'Reasons for carrying out works' column, the capacity of an asset is emphasised, as opposed to the place it serves. Following this pattern, none of the thirty listed proposals, outlined in the *Long Term Development Statement* (ENW, 2017d), state the reason for carrying out works in reference to the specific electricity demands of a place. Indeed, the condition and capacity of assets take centre stage.

LONG TERM DEVELOPMENT STATEMENT

GRID SUPPLY POINT	AREA OF THE NETWORK AFFECTED	INFORMATION ON THE AREA	OUTLIINE OF WORKS	REASON FOR CARRYING OUT WORKS	EXPECTED TIMESCALE	EXPECTED IMPACT ON THE DISTRIBUTION NETWORK CAPABILITY
Stalybridge GSP	Denton East Primary	Denton East primary is located to the east of Denton Town in Tameside metropolitan borough of Greater Manchester. The primary supplies approximately 10,300 customers	Replace existing 55 year old 10/14MVA units with new modern equivalent 11.5/23MVA units	The condition of the existing transformer	Work has started on site and the new transformers are expected to be commissioned by March 2019	Firm network capacity at the primary substation will increase to 23MVA
Stalybridge GSP	Queens Park Primary	Queens Park primary lies in east Manchester and is supplied from Stuart St BSP. It supplies approximately 8,400 customers	Replace is to replace the existing 55 year old and 56 year old 10/14MVA primary transformers with new 11.5/23MVA units	The condition of the existing primary transformers	Work has started on site and is expected to be completed by January 2018	Firm capacity will increase to 19MVA with the 33kV circuits from Stuart St BSP being the limiting factor
Whitegate GSP	Werneth Primary	Werneth primary is located in Oldham, Greater Manchester and supplies approximately 7,700 customers	Replace the existing 50 year old HV switchgear with modern equivalent asset	The condition of the existing HV switchgear	Work is scheduled to start on site in July 2018 and completion is expected by May 2019	The project will increase increase HV fault level capability at Werneth primary
Whitegate GSP	Shaw Primary	Shaw primary is located in Shaw in the Oldham metropolitan borough of Greater Manchester. The primary supplies approximately 9,300 customers	Replace existing 56 year old 10/12.5MVA and 27 year old 11.5/23MVA units with new modern equivalent 11.5/23MVA units	The condition of the existing transformers	Work has started on site and the new transformers are expected to be commissioned by March 2019	Firm network capacity at the primary substation will increase to 23MVA

Electricity North West/Long Term Development Statement/November 2017 Page 28 of 28

Figure 27: Example of ENW's investment plans as outlined in the *Long term development statement* (ENW, 2017d, p. 28)

The asset-oriented rationale for investment is confirmed in explanations of the expected impacts of proposed investments, with increased ‘firm capacities’ counting as a central benefit. Firm capacity concerns:

> The capacity available immediately after the loss of the most critical branch without manual intervention but includes any capacity made available due to automatic switching. It also includes estimated contribution to capacity from connected distributed generation. (ENW, 2017d, p. 17)

Firm capacity, in turn, represents a measure of a HV substation’s resilience in reference to its wider connections (ENW, 2017d). In the case of the 2017 upgrading of the Queens Park Primary, for example, it is noted that the increase of the substation’s capacity would be limited by ‘the 33 kV circuits from the Stuart St BSP’ (Figure 27) (ENW, 2017d, p. 28). The geography and affordances of the ‘mini-grid’ consequently form a key component of the investment narrative articulated by ENW concerning the upgrading of the Queens Park Primary (ENW, 2017d, p. 28).

The foregrounding of ‘mini-grid’ capacities and the affordances of hardware also take centre stage in ENW’s representation of how the organisation handles the spread of Distributed Generation (DG) (ENW, 2019b). DG concerns 'generation that is designed to operate in parallel’ with ENW’s network and generally takes the form of smaller-scale hydro, wind or solar projects (ENW, 2019b).

To handle and try to inform where DG takes place, ENW produces a map which details where a new DG connection, up to 10 MW, could be connected to a particular 33 kV substation without breaching the relevant substation’s fault level (Figure 28) (ENW, 2018e). The fault level ‘is the potential maximum fault current that will flow when a fault occurs… this increases as new generators/motors are connected to the network’ (ENW, 2018f, p. 5). Fault levels are dictated by the rating of hardware that comprise a network (ENW, 2018f). The established capacities of assets, which vary from one ‘mini-grid’ to another, are thus crucial in terms of offering opportunities to accommodate DG, whist also avoiding expensive forms of reinforcement. As with the ordering of discretionary capital investment proposals, the capacities of ‘mini-grids’ and the assets they comprise are thus emphasised by the way ENW seeks to manage DG, dictating, in this instance, where new sites of generation can take shape at minimum cost.

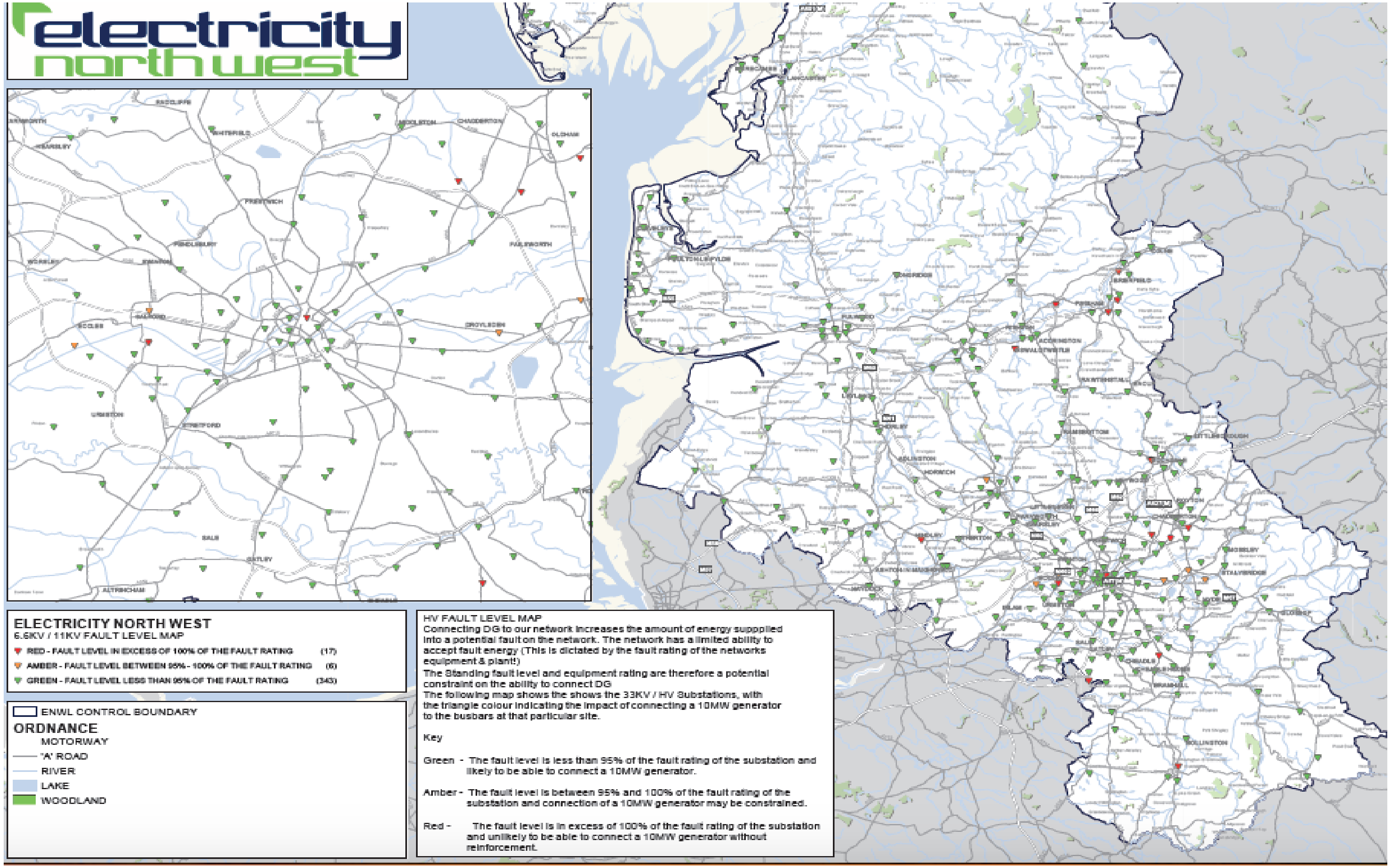

Figure 28: ENW's HV fault level map for 33 kV substations (ENW, 2018e)

A similar asset-oriented approach is also evident in the way ENW manages 'hotspots' across its network. Hotspots are areas on the network 'where demand is high and in danger of exceeding existing capacities for provision' (Chappells, 2003, p. 162). They are identified by a monitoring the load data from substations 33 kV and upwards (ENW, 2019c). By monitoring the load data of HV substations, ENW is able produce a picture of how an asset is performing and whether it is likely to breach its load capacity as a consequence of additional connections, be they for generation or consumption. This view is particularly informative for developers looking to get a new connection and wishing to get an idea of whether their development will involve the expense of network reinforcement. Figure 29 represents a subset of open data concerning primary substation headroom, which is shared by ENW to help developers calculate the impact of their proposed developments (ENW, 2019c). Following and contributing to the asset-oriented representation and view of the network, each entry is listed with details concerning the 'mini-grid' it knits into and its broader affordances (Figure 29).

Primary Substation Headroom												
Primary Substation	Voltage (kV)	BSP Group	GSP Group	Primary Substation Location		Demand Headroom (MW)		Generation Headroom N-0 -(MW)			Battery Storage Headroom N-0 -(MW)
				Easting	Northing	Firm	N-0	Inverter Based	Synchronous - LV	Synchronous - HV	
CENTRAL MANCHESTER	6.6	STUART ST	STALYBRIDGE	384852	397718	0.0	4.4	42.3	9.4	6.8	4.4
CHADDERTON	6.6	CHADDERTON	WHITEGATE	389161	403872	8.9	8.9	26.1	4.2	3.1	8.9
CHAMBERHALL	6.6	BURY	KEARSLEY	380280	411215	1.8	7.1	11.2	2.0	1.4	7.1
CHAPEL WHARF	6.6	FREDERICK RD	KEARSLEY	383499	398634	0.0	6.3	7.0	2.0	1.4	6.3
CHASSEN RD	6.6	BARTON	CARRINGTON	375542	394453	2.8	13.7	7.0	2.0	1.4	7.0
CHATSWORTH ST	11	BARROW & SANDGATE	HARKER / HUTTON	319188	470003	6.1	13.5	32.2	10.2	7.3	13.5
CHEADLE HEATH	6.6	ADSWOOD	BREDBURY	387062	389054	4.6	8.1	22.3	11.5	8.4	8.1
CHEADLE HULME	11	ADSWOOD	BREDBURY	387386	386308	7.4	12.0	31.6	13.1	9.4	12.0
CHEETHAM HILL	6.6	AGECROFT	KEARSLEY	383606	402218	2.4	5.9	24.8	15.5	11.3	5.9
CHELFORD	11	MOSS NOOK	SOUTH MANCHESTER	382184	373490	7.9	14.9	11.2	2.0	1.4	11.2
CHESTER RD T11 & T12	6.6	STRETFORD	SOUTH MANCHESTER	381030	396165	0.0	0.9	24.2	8.4	6.1	0.9
CHESTER RD T13	6.6	STRETFORD	SOUTH MANCHESTER	381040	396175	1.8	13.4	19.0	19.0	17.1	13.4
CHORLEY SOUTH	11	WRIGHTINGTON	PENWORTHAM WEST / STANAH	358658	417041	2.8	6.3	23.8	9.1	6.7	6.3
CHORLTON	6.6	WEST DIDSBURY	SOUTH MANCHESTER	381411	393754	4.5	10.5	11.2	2.0	1.4	10.5
CHURCH	6.6	HUNCOAT	PADIHAM	374687	428919	5.5	11.5	17.9	11.4	8.3	11.5
CLARENDON RD	6.6	BLACKBURN	PENWORTHAM EAST / ROCHDALE	369051	429883	0.0	3.0	30.9	8.2	6.0	3.0

Figure 29: 33 kV primary substation headroom data provided as part of ENW heatmap tool (ENW, 2019c)

Reinforcing this hardware-oriented and regional view of the electricity system, there is no discussion of Manchester's or Greater Manchester's electricity networks in ENW's *Annual Report and Consolidated Financial Statements* (ENW, 2017c), the *Long-term Development Statement* (ENW, 2017d) or the company's most recent *Innovation Strategy* (ENW, 2018c). While the connections between electricity networks and urban development have formed central themes in academic writing (Chappells, 2003; Moss, 2008; Walther, 2016), this is not how ENW tends to represent its work. The depiction of the network in ENW reports, maps and datasets suggest that the organisation is less concerned with the spatial dynamics of the city and more focused on managing the distributed capacities of 'mini-grids'.

This regional approach is neither unique to ENW or of its own making. The methods ENW employ relate to wider notions, ideas and rules regarding how to organise and manage regional distribution networks. In this regard, the organisation's approach dovetails with the work of other Distribution Network Operators, and their combined work as a part of the Electricity Networks Association (ENA) (ENA, 2018). As Hughes (1983) and Harrison (2013) have similarly shown, the spatial organisation of electricity systems thus affects how networks are managed and how they develop over time. The production of a 'regional' and hardware-oriented view and version of the electricity system is, in this sense, tied to the geographical and technical remit of ENW and how that is organised.

The market-focused international view of the electricity system

Another professional worldview of the electricity system is represented in and articulated through the work of the European Network of Transmission System Operators for Electricity (ENTSO-E), National Grid (NG) and National Grid Electricity Transmission (NGET). These organisations facilitate the transmission of electricity across vast geographical distances and make the transnational electricity market viable. Focusing on how these organisations represent their work, I discern an international and market-focused view of the electricity system.

The international view and version of the system are not determined by the dynamics of cities or regions. Instead, what counts, is the transnational marketized distribution of electricity and a related set of organisational challenges, rules, aims and objectives. The relationships between practices and the organisation of electricity infrastructure, and the constitution of demand, are framed in these terms. From this point of view, Central Manchester's land use change appears to be afforded and enabled by the production of an internationally configured electricity system, which is organised around a logic little to do with the changing form and function of Manchester or any other city.

I articulate an account of the international and market-focused view of the electricity system by first describing the physical organisation of this network. I subsequently explain how NG, NGET and the ENTSO-E represent and conduct their combined work.

The organisation(s) of the international network

The electricity transmission network that covers Britain is owned and maintained by three different regional transmission companies: National Grid (NG) own and maintain the transmission network in England and Wales, Scottish Power Transmission Limited in southern Scotland, and Scottish Hydro Electric Transmission in northern Scotland (OFGEM, 2019). Although owned and maintained by different organisations, each of the various portions of Britain's transmission network are operated by NGET, a subsidiary of NG (NG, 2017a). Representations of the transmission network NGET operates across England, Scotland and Wales are provided by Figures 30 and 31 (NG, 2017b).

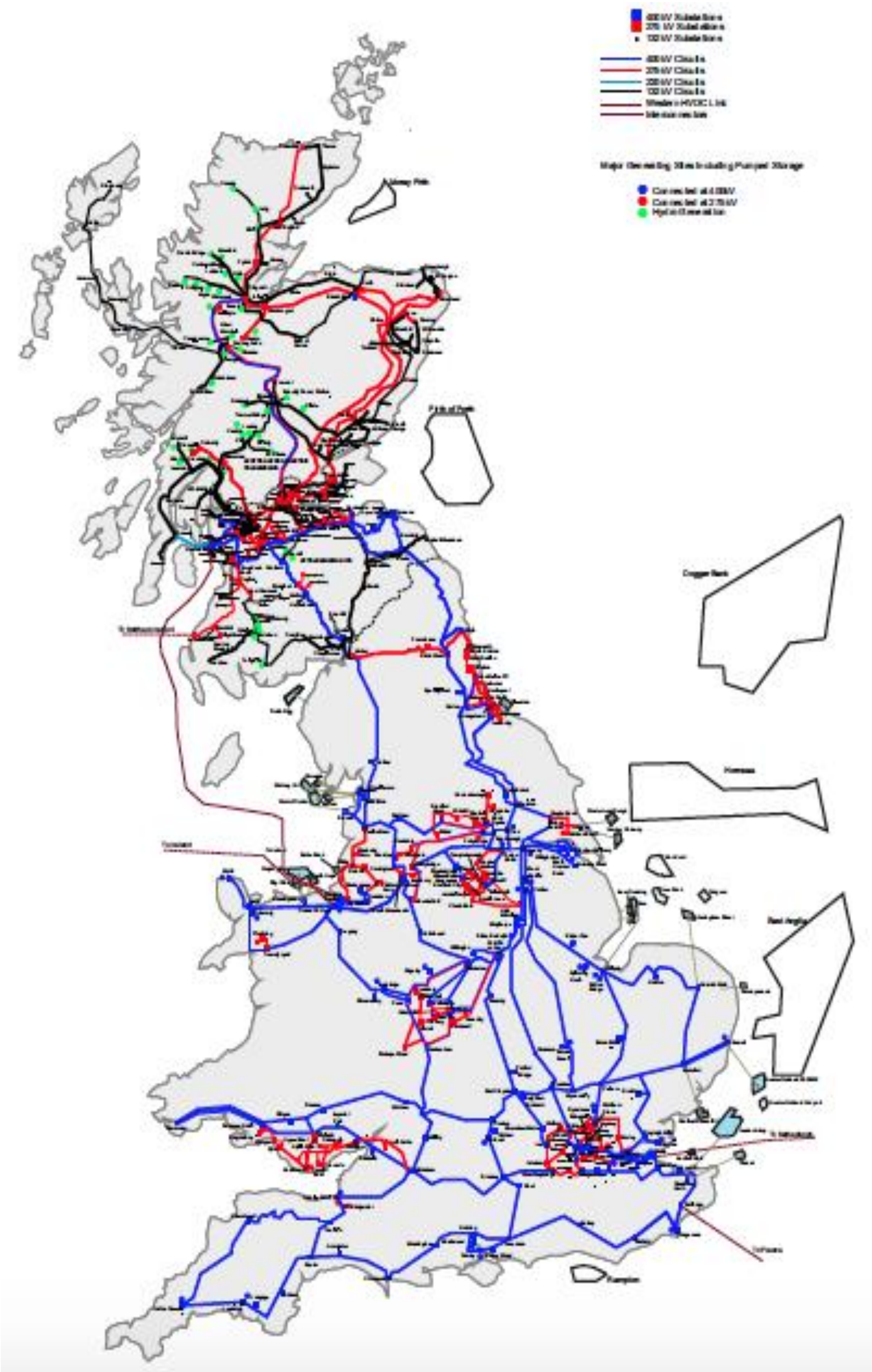

Figure 30: Map of NGET network (NG, 2017b)

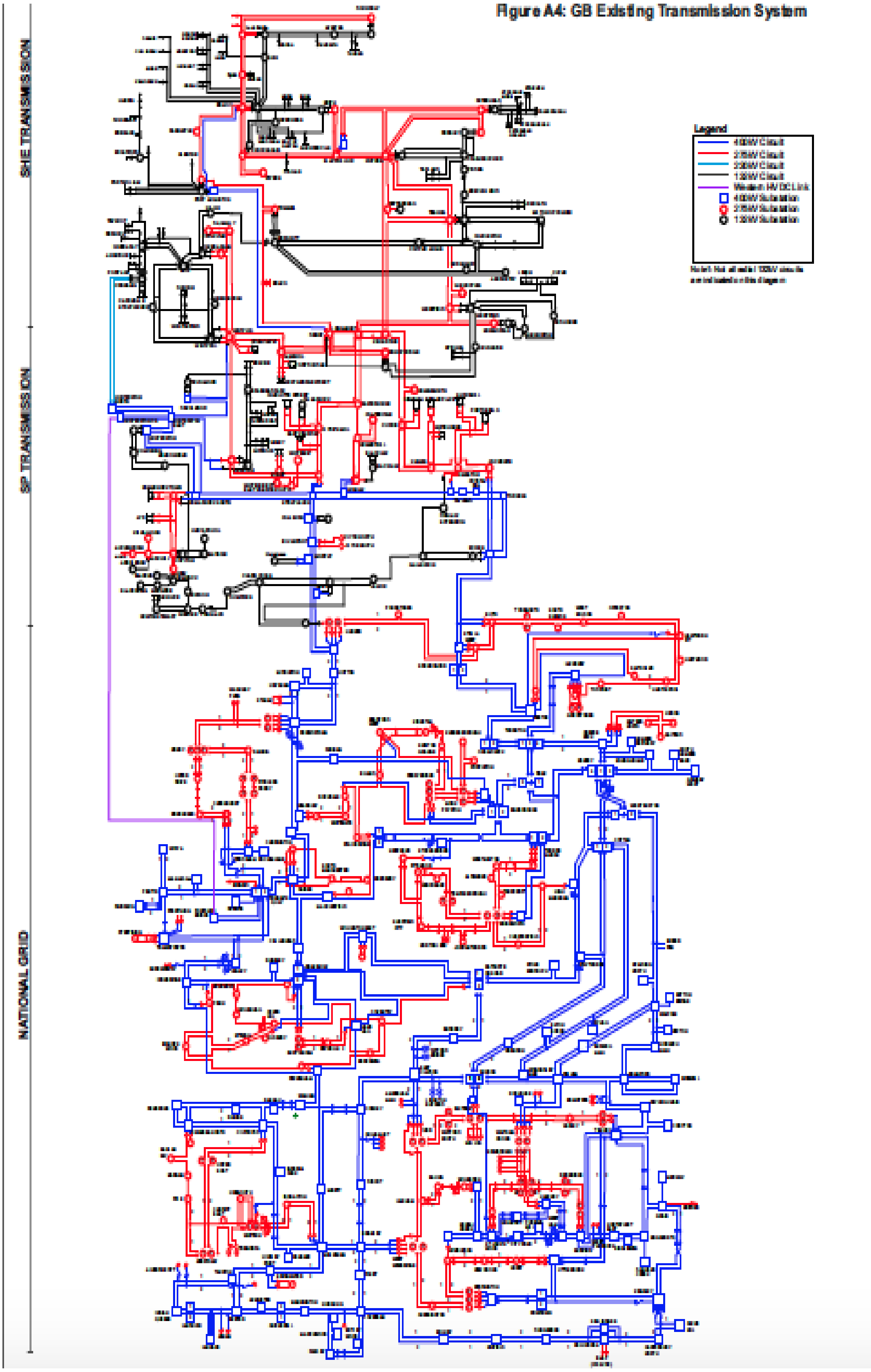

Figure 31: Schematic representation of NGET network (NG, 2017b)

The transmission network NGET operates is made up of 4,474 miles of overhead line, 969 miles of underground cable and 346 substations (NG, 2018b). It is NGET's responsibility to make sure that Great Britain's electricity 'supply and demand are balanced in real time' (NG, 2017a, p. 8).

The balancing act NGET performs involves managing the flow of electricity around Great Britain and to and from several other countries (NG, 2017a). As of 2017, Great Britain was 'linked via interconnectors with France, Ireland, Northern Ireland and the Netherlands' (NG, 2017a, p. 2). 'Additional interconnector projects…, include three interconnectors currently in construction to France, Norway and Belgium, [and] a link to Denmark' (NG, 2018b, p. 3). The existing forms of interconnection, which are depicted in Figure 32 (ENTSO-E, 2019), enable the transnational exchange of electricity (BEIS, 2017a). Since the current interconnection with France opened in 1986, the UK has annually been a net importer of electricity (House of Commons Library, 2018b). The High-Voltage Direct Current (HVDC) connections, which have enabled the UK to become a net importer of electricity, also mean that Central Manchester is supplied by a network that is wired into a wider interconnected international electricity system.

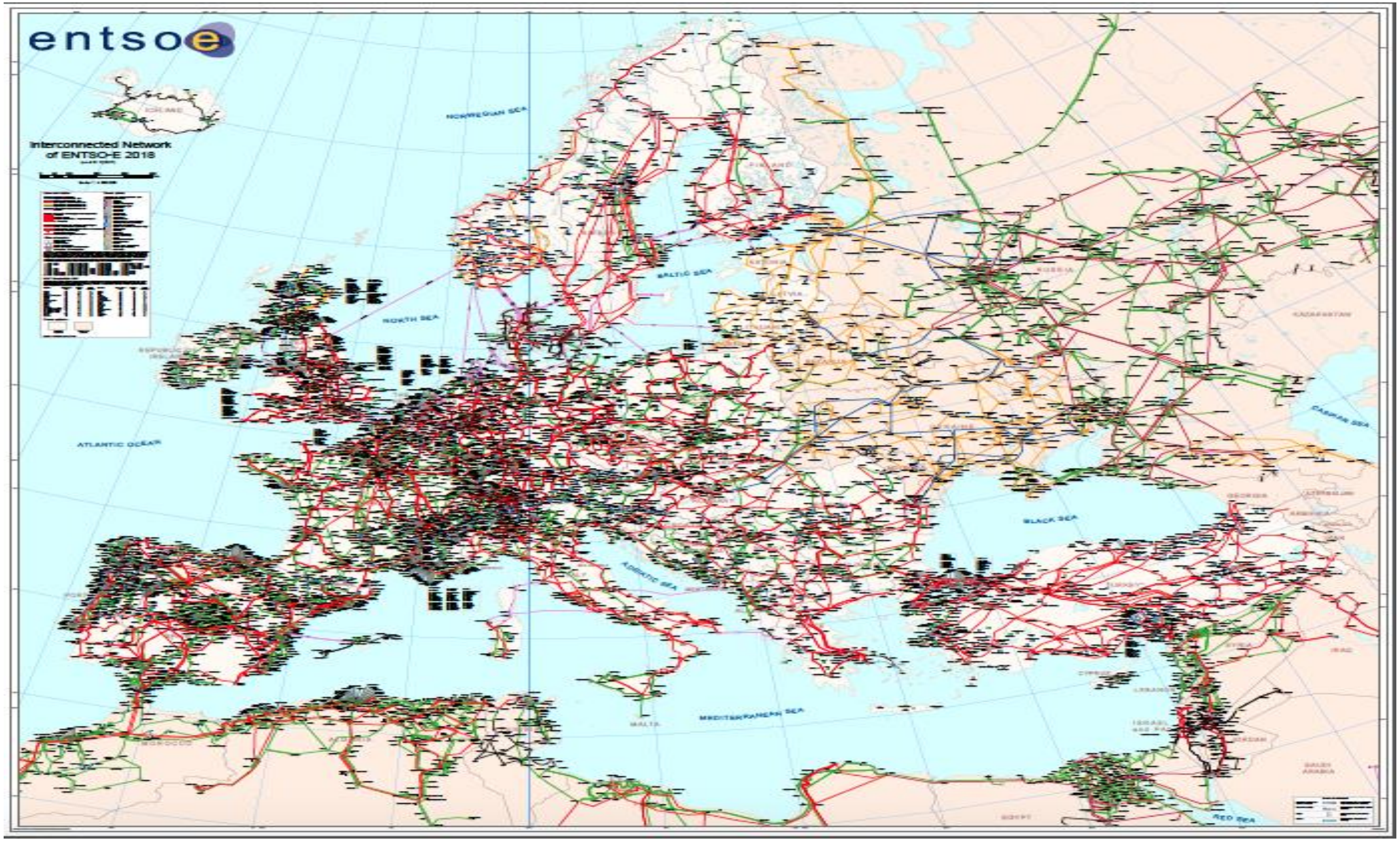

Figure 32: The ENTSO-E (2019) transmission system

The international transmission system represented by Figure 32 is regulated by the European Network of Transmission System Operators for Electricity (ENTSO-E). ENTSO-E is comprised of forty-three electricity transmission system operators, representing thirty-six countries (ENTSO-E, 2017). The organisation was established in 2009, as an outcome of *European Parliament Regulation EC No 714/2009* and its central aim concerns the increasing market liberalisation of electricity and gas, in order to support the European Union's broader climate change agenda (ENSO-E, 2017). The ENTSO-E network serves over five-hundred million citizens (ENTSO-E, 2017).

Making the international market-focused view and version of the electricity system

The scope, boundaries and constitution of a market-focused international professional worldview and version of the electricity system are captured in visual representations of the network and in plans, policies and related investment projects. The international and market-focused view of the electricity network is, for example, particularly evident in the EU regulatory framework for electricity markets, which ENTSO-E operates in reference to.

Since ENTSO-E's inception in 2009, a series of EU packages have been deployed, which support increased interconnection between member states' electricity networks (Newbery et al., 2016). Following this trend, in 2011, the *Third International Energy Market Package* was introduced. A key objective of this package concerned the need to 'urgently upgrade Europe's networks, interconnecting them at the continental level, in particular to integrate renewable energy sources' (EU, 2011, cited in Newbery et al., 2016, p. 254). Building on this aim, consistent efforts have been made to tie different networks together. These efforts have included material changes and upgrades, which create physical compatibility, and the related introduction of rules and regulations that support the transnational trading of electricity. As noted in the *In-short: Regional Investment Plans* publication (ENTSO-E, 2018b, p. 4), 'efficient transition requires efficient markets and efficient markets require sufficient infrastructure which will create value'.

To create an efficient electricity market, the EU has incrementally introduced the Target Electricity Model (TEM) across member states, which is a key part of ENTSO-E's operations (Newbery et al., 2016). The TEM 'defines a number of market design elements' and was implemented in the UK in 2014 (Oxera, 2013, p. 1). The TEM is designed around capacity calculations, capacity allocation and congestion, management, balancing and governance, in order to facilitate the creation of a fair international electricity market (European Union, 2009). The creation of a fair electricity market has involved the establishment of 'a single auction platform, Euphemia (Pan-European Hybrid Electricity Market Integration Algorithm)' (Newbery et al., 2016, p. 254). Euphemia means that 'wholesale electricity prices… [are] equalized across boundaries' a day prior to generation and transmission (Newbery et al., 2016, p. 254). Before this coupling of wholesale prices and the implementation of the day-ahead market, 'traders faced the risk that on the day the trade would no longer be profitable', with possible price fluctuations from one day to the next in and between energy sources across member states (Newbery et al., 2016, p. 254). The unifying focus here, is the international market and constituting a system, premised on rules and the ordering of hardware, which facilitates the transnational exchange of electricity.

To support the ongoing constitution of a fair and productive transnational market for electricity, the European Commission (EC) estimated, in 2011, that €200 billion of investment would be needed in energy infrastructure Europe-wide by 2020 (EC, 2011). €140 billion of this would be required for electricity transmission, storage and smart grid applications (EC, 2011). Looking further ahead, a series of extensive investment plans, concerning changes required by 2030 and 2040 are outlined by the ENTSO-E (2018b). These plans include projects that increase network capacity, interconnection and compatibility (Figure 33) (ENTSO-E, 2018b, 2018c).

Figure 33: ENTSO-E 2018 – 2040 project map (ENTSO-E, 2018c)

Increasing the network's transmission capacity is particularly important, as greater interconnection and network compatibility mean that electricity from different generators and areas can be exchanged (ENTSO-E, 2018b). Interconnection is also seen as a particularly crucial part of supporting the uptake of renewables, with solar generation in Spain, for example, adding to the generation mix for the whole of Europe (ENTSO-E, 2018b). The money invested in interconnection thus supports the aim of facilitating a European-wide electricity system and market, which, it is argued, supports attempts to meet climate change targets (ENTSO-E, 2018b).

To increase European-wide network capacity, interconnection and/or compatibility, ENTSO-E currently has 166 transmission and fifteen storage projects, which are at different stages (ENTSO-E, 2018c). These projects are represented by Figure 33. Included is: 'Project 74 - Thames Estuary Cluster (NEMO-Link)' (ENTSO-E, 2018d). Coming at an estimated total cost of €660 million, Project 74 involves the establishment of a HVDC connection between the UK and Belgium. To facilitate this link, NGET is responsible for reinforcements to the UK network, including the development of a 'new 400kV double circuit and new 400kV substation in Richborough' (ENTSO-E, 2018d).

The ongoing constitution of an international view and version of the electricity system thus takes shape through the work of multiple organisations, including ENTSO-E and NGET, which are connected through trade and governance agreements and an increasingly interconnected material system purposefully shaped to facilitate the transnational market exchange of electricity. Developing this point, NG investments, such as the 2006 £44 million extension of the 400 kV Stalybridge substation and the refurbishment of the adjacent 275 kV GSP's switch gears, both of which feed the Central Manchester 33 kV Primary, can be taken to represent examples of the extensive work that goes into making, managing and producing an international version of the electricity system (ABB, 2016). Likewise, NG's maintenance of England and Wales' transmission network is, when read in relation to the context described, part and parcel of a larger project shaped around the management of an international system capable of facilitating the circulation and exchange of electricity in and between different countries.

This international view means that the other instances of infrastructural change, discussed in this and the previous chapter, including the development of the Central Manchester 33 kV Primary and the upgrading of the Queens Park 33 kV Primary, are part of the orchestration of a transnational and marketized electricity system. This view not only complicates the account I provided in Chapter five, regarding the development of the Central Manchester Primary, but also suggest that all infrastructural changes, regardless of scale, can be viewed as part and parcel of the configuration and ongoing production of an international version of the electricity system. Following this logic, one might argue that the electricity system represented in ENW publications is overshadowed, becoming an appendage to the international version of the system. The £960 million committed by ENW to network investment between 2015 and 2023 can, for instance, be read as part and parcel of the enactment of an international version of the system, while also simultaneously appearing to be the product of ENW's regional and hardware-oriented approach (ENW, 2017d).

Equally, the Manchester-city-centric view of the electricity system is complicated by the ongoing production of an international version of the electricity market and network, with the specific needs of cities and the political aims and objectives of city authorities appearing to have little meaning or relevance. There is, for example, no mention of the management of electricity in relation to a specific city in NG's (2017a) *Electricity Transmission plc Annual Report and Accounts 2016/17*. Within ENTSO-E's (2017) *Annual Report*, the city, urban energy systems or the urban organisation of electricity are also missing. Instead of the city, the regions associated with the organisation and management of transmission networks within European community member states take precedence for ENTSO-E. This international and spatial view connects with the key legislative act that led to the constitution of the ENTSO-E. As captured in EU 'REGULATION (EC) No 714/2009':

> Given that more effective progress may be achieved through an approach at regional level, transmission system operators should set up regional structures within the overall cooperation structure, whilst ensuring that results at regional level are compatible with network codes and non-binding ten-year network development plans at Community level. (EU, 2009)

As opposed to the needs of any city, it is thus the spatial resolution of the EU that is emphasised in the regulations that inform ENTSO-E's work.

Bringing the examples discussed in this section together, I have introduced and described the constitution and organisation of an international and market-focused view of the electricity system, which is crafted through the work of several organisations. The representation and enactment of an international system challenge and complicate the professional worldviews discussed in the previous sections. Specifically, tensions arise as a consequence of showing how the politics of cities and the regional organisation of electricity are complicated by the production of an international version of the electricity system.

The implications of three views and versions

This far, this chapter suggests that multiple professional worldviews of the electricity system coexist and that these are the product of different organisational aims, objectives and ways of defining challenges, including meeting the demands of electricity-demanding practices. These positions are important for how and why investments and forms of network extension unfold.

In this section, I consider what my description of three professional worldviews of the electricity system means for the key themes and questions of this thesis.

A key implication of my analysis is that the relationships between land use change in Central Manchester, the constitution of electricity demand, and the organisation of the electricity system are not one-dimensional but that they take different forms at different spatial scales. This is to say that the constitution of electricity demand in Central Manchester involves and depends on the simultaneous enactment of different views and versions of the electricity system and electricity demand, which are not always clearly to do with the city or a city's political management. Important here, is the idea that the electricity network and related notions of demand take many forms and guises. This idea complicates and challenges the tendency to frame electricity consumption and demand as urban issues, which are a product of, manifest in and possible to manage at the scale of the city - particularly in order to tackle climate change (Betsill and Bulkeley, 2006; Rosenzweig et al., 2011; Bulkeley, 2014; Carter et al., 2015; C40, 2019; Core Cities, 2019).

As many authors argue, patterns of urban development and electricity infrastructures are interlinked and to some extent my research design and my approach reflects this view (Hughes, 1983; Frost, 1993; Graham and Marvin, 2001; Chappells, 2003; Moss and Francesch-Huidobro, 2016). Indeed, I have tried to show how changes in land use – whether rooted in Manchester or not – are related to forms of infrastructural investment in the city. However, as also demonstrated in this chapter, as one moves up the voltage levels and focuses on the management and maintenance of larger network assets, such as the Stalybridge GSP, the connections between practices, infrastructure and sites of demand change shape. It therefore no longer makes sense to concentrate exclusively on the city or representations of it in some bounded way in order to understand the connections between land use change, the constitution of demand and the ordering of the electricity system. The Stalybridge GSP does not, for example, only supply and facilitate the constitution of demand in the Northern Quarter (NQ) and Central Manchester. This is not to say that electricity demand is not constituted in the city, but rather that the constitution of electricity demand simultaneously takes shape at different scales and is constituted, facilitated and enabled through the work of organisations involved in supplying electricity and managing hardware at different scales.

Developing this point, my analysis in this chapter also implies that the extension of electricity systems is not one-dimensional. At one and the same time, instances of investment in the hardware that supplies electricity can be understood to be the product of making a Manchester-city-centric network, the 'mini-grid' asset-oriented management of a regional network, or connected with the international and marketized generation, transmission and supply of electricity.

By highlighting how instances of infrastructural change can be read through and interpreted as simultaneously the product of various professional enactments of views and versions of the electricity system, the analysis presented in this chapter complicates somewhat linear or causal explanations of how infrastructures develop as a consequence urban processes (Tarr and Dupuy, 1988; Graham and Marvin, 2001; Monstadt, 2009). My analysis also suggests that authors who mobilise the Multi-level perspective (MLP) as an analytic scheme and distinguish between micro, meso and macro 'levels' of energy transitions need to take account of the coexistence of different scales and discourses. Mobilising MLP, authors have tended to describe and explain various technological transitions and infrastructural changes as phenomenon formed at a national scale (Correljé and Verbong, 2004; Geels, 2005; Verbong and Geels, 2007; Geels et al., 2016; Olufolahan et al., 2018). As opposed to emphasising and privileging either the city or a national setting, I have shown how infrastructural change and development can be simultaneously connected with and interpreted as an outcome of the enactment of different versions of the electricity system. In turn, this chapter complicates the idea of 'the' electricity system and implies that it is important to appreciate and explore multiple explanatory rationales when trying to understand and explain why electricity systems change over time.

Summary

In this chapter, I have articulated three different professional worldviews and versions of the electricity system. Developing my analysis, I have suggested that the three views and versions of the electricity system described have implications for conceptualising and understanding the links between land use change and the electricity system, the handling of demand, and the related organisation of hardware. Within the final chapter, I consider the connections between each empirical study and draw out several insights and implications of this thesis and what it means for conceptualising and studying the future constitution of hardware that supplies electricity to Central Manchester.

Chapter seven: Conclusion

Introduction

I have used Central Manchester as a case study site to study how electricity consumption and supply make each other at different scales, over time. To carry out my task, I developed four cases. Each case built on the premise that electricity demand can be usefully conceptualised as an outcome of the performance of and co-constitutive relationships between social practices (Shove and Walker, 2014). Co-constitution refers specifically to the idea that practices, be they linked with electricity consumption or supply, depend on and shape each other - networks not only support certain activities, they are also built and extended over time in relation to demanding practices (Hughes, 1983; Shove, 2016). In this project, I have examined the co-constitutive relationships between practices linked with land use change, such as town planning, policy making, and trends in investment, and those connected with the organisation of the electricity network. By discerning and studying these relationships, I have been able to provide new insights and ideas about how electricity consumption and supply take shape and in particular about how they make each other at different scales.

The account I develop rests on a distinctive approach to issues of scale, temporality, and multiplicity. These themes and my approach to them are in part derived from my empirical work and from a research design that has allowed me to show that electricity consumption and provision in one location are not only defined in that location and at one time. 'Local' histories of land use, policy and provision are certainly a feature of changing consumption and supply, but so too are changes that are not 'of that area', though they materialised within it. This insight holds significance and has implications for future research because it shows that studying sited demands involves engaging with dispersed connections, between multiple practices, which shape and inform how demanding sites come about and change over time. As a consequence of showing that electricity consumption and supply are not strictly of a site or under the control of a single agent, this thesis and the insights generated also have implications for local and national policy makers, city authorities, and town and network planners. As explained in Chapter one, these groups are commonly understood to be in a privileged position to be able to shape and mitigate electricity consumption and supply (Betsill and Bulkeley, 2006; Rosenzweig, 2011; Bulkeley et al., 2014; Carter et al., 2015; Electricity North West, 2018a, 2018b, 2018c National Grid, 2018a; C40, 2019; Core Cities UK, 2019). My account suggests that these actors play different roles in the constitution of electricity demand over time and at different scales, but also that they are only components of a multiplicity of relationships that underpin the co-constitutive shaping of electricity consumption and supply. With the roles played by these actors differentiated and limited, in part by their connections with each other, this thesis generates new and different ways of thinking about how electricity consumption and supply might be shaped to meet key aims relating to climate change.

In this chapter, I unpack and develop the implications of my research by first considering the role of each case study and what each reveal. This move reflects the epistemological argument, outlined in Chapter two, that the methods used to study a phenomenon constitute the phenomenon studied (Latour and Woolgar, 1979; Barad, 2003; Cerwonka and Malkki, 2007; Sayer, 2010). Having explained the role of each study and how they relate to each other, I work through and unpack the three themes that emerge from this project:

1. Scale – The formation of electricity demand has sited and dispersed features.
2. Temporality - Uneven periods and moments of consumption and supply punctuate the constitution of demand.

3. Multiplicity - Manifold connections between multiple practices inform the constitution of demand over time and across scale.

Taking these ideas forward, I discuss the broader implications of my research for thinking about the future of electricity consumption, supply and thus demand in Central Manchester. This discussion demonstrates the value of this thesis, particularly for researchers interested in catching sight of the ongoing and future-shaping of demand in the present. In the final section, I outline the key issues and new questions this thesis raises for researchers and policy makers, city authorities, and town and network planners.

The insights of each study

My first investigation - Study one (Chapter three) – involved an examination of changes in land use. This represented a first step in capturing the changing history of electricity consumption and supply in an area of Central Manchester (the Northern Quarter (NQ)). Working with land use change statistics, as proxies for practice bundles, revealed a spike in residential land use change in the NQ between 2000 and 2012 and an ongoing churning of commercial land uses, particularly between 1998 and 2014. These overlapping periods of change signal that the sited relationships between electricity consumption and supply do not unfold evenly over time. Different patterns of demand - be they linked with residential or commercial forms of land use - form over certain periods, depending on and structuring the sited organisation of infrastructure. The addition of 6.6 kV substations with new mixed-use residential developments reflects this relationship.

Although revealing spikes in land use change and the sited formation of demand over time, Study one does not reveal anything about what informed the pronounced shift to residential land use in the NQ between 2000 and 2012 or the churning of commercial land uses in the area, particularly after 1998

(Chapter three). In this regard, Study two (Chapter four) provides a way of addressing these issues.

This investigation – focusing on trends and events that were materialised in Manchester - shows that the land use changes discussed in Chapter three were not exclusively made in the city. The changes outlined were, instead, part and parcel of intersecting practices and related trends in planning, investment, the ordering of higher education, the delivery of an international sporting event, and the recovery from an IRA bomb. The related practices and trends were not clearly ordered by the boundaries of the city, although they do knot together there, informing punctuated moments of land use change, which are enabled by the electricity network and, in time, responded to by network planners. My 'global-local' account of the city's land use change contrasts with those that foreground the role of Manchester's 'entrepreneurial' local authority (Williams, 2000, 2002; Peck and Ward, 2002; Ward, 2003; Cook and Ward, 2011). My work also complicates accounts of network development that emphasise the local shaping of infrastructures, at the hands of political actors and key players, including city authorities and engineers (Winner, 1980; Hughes, 1983; Frost, 1993; Graham and Marvin, 2001; Moss, 2008).

Up until this point, neither Study one or Study two provided any precise detail about the organisation and management of the electricity network in relation to the use of the city and the changing consumption of electricity in Manchester. It made sense and was important to turn attention to the organisation of the electricity network.

Study three, based on the 2009 development of the Central Manchester Primary, signals this turn. I specifically examined how this instance of network investment connected with the types of trends in land use and demand outlined in Chapter three and Chapter four. Study three shows that new substations like this particular 'Primary' are only needed when situated capacities and thresholds are in danger of being breached. As others note, infrastructural investment is very lumpy (Star, 1999; Knaap et al., 2001). In this case, the lumpy instance of network investment was occasioned, in part, as a response to the trends in land use outlined in Chapter three, such as the spike in the city's residentialisation between 2000 and 2012.

Given the insights generated as a consequence of conducting Study one and Study two, my discussion of the Central Manchester Primary treats this investment as a product of sited and dispersed relationships. It is sited because it is anchored in the city and it is connected with land use change in Central Manchester and the historical affordances of the network. Yet, it can also be interpreted as an outcome of dispersed relationships because the land use changes that led to the development of the Central Manchester Primary are not clearly to do with the city itself. The sited and dispersed positioning of the Central Manchester Primary complicates accounts of infrastructural change that emphasise politically bounded and localised relationships as the motors of network development (Winner, 1980; Graham and Marvin, 2001; Amin, 2014; Moss and Francesch-Huidobro, 2015; Neill, 2016). Likewise, accounts that foreground broader innovations, at the cost of local relationships, are also problematised as a consequence of overlooking sited specificities (Correljé and Verbong, 2004; Verbong and Geels, 2007; Geels et al., 2016; Olufolahan et al., 2018). Instead, my interpretation of the Manchester Primary results in an account of the connections between electricity consumption and supply aligned with those that acknowledge the simultaneously dispersed and localised features of infrastructural change (Hughes, 1983; Summerton and Coutard, 1994; Shove, 2016).

Sticking with the electricity infrastructure, Study four recognises that the Central Manchester Primary Substation is only a piece of a bigger network, which stretches out beyond the city. By examining the wider organisation of the network, I show that multiple interpretations of demand and of the electricity network coexist and in various ways shape, enable and respond to each other. Examples of these interpretations are found across documents produced by various interested parties, including Manchester City Council, Electricity North West, National Grid and the European Network of Transmission System Operators of Electricity (see Appendix 3).

Land use changes in Central Manchester are seen to play both an important and ambiguous role for the different parties referred to. At times, the aims and ambitions of local political actors and related demands, conceptualised at the scale of the city, inform features of planned network developments. In other instances, the needs of the city or the aims of local authorities do not clearly feature as part of the electricity system's organisation and development. This is because different discursive formations of scale and demand are simultaneously implicated in the framing and representation of the network and related infrastructural investments. There is, in these terms, more at stake than sited land use changes and network thresholds in the city, with electricity consumption and supply simultaneously co-constituted at various scales.

Three emergent themes

Three themes, concerning the relationships between electricity consumption and supply, emerge as a consequence of bringing the four studies together. These themes revolve around and generate different ideas about how to conceptualise and examine the dynamic constitution of electricity demand over time and across different scales.

Scale: The sited and dispersed formation of electricity demand

Scale is a constant theme and feature of my account of the relationships between electricity consumption and supply. Scale is a contested topic in human geography and in practice theory (Marston, 2000; Knorr Cetina, 2005; Nicolini, 2009). I first take scale literally, taking Manchester to represent the local and 'small-scale', and the 'large-scale' to be beyond the city. However, I also go onto reconceptualise this relationship, showing how multiple discursive scales are implicated in the ordering of consumption and supply.

Like many others, I specifically show that the relationships between electricity consumption and supply are informed by sited connections, shaped at a local scale (Winner, 1980; Summerton, 1992; Latour, 1996; Amin, 2014; Moss and Francesch-Huidobro, 2016). This is because relationships between consumption and supply take shape and are embedded in the histories of particular locations. Land use changes in the Northern Quarter and the area's residentialisation, between 2000 and 2012, were enabled by and demanded sited network investments (Chapter three). The investment in the Central Manchester Primary also represents a situated response to land use changes in the city, no longer afforded by the distributed historical capacities of the network by 2007. However, my research also complicates this local account of the relationships between electricity consumption and supply. Chapter four and Chapter six see 'local' relationships cast in wider contexts, which mean situated changes in consumption and supply are not necessarily of a site's own making. Both the city's land use change and the hardware that supplies electricity to the NQ and Central Manchester are shown to have various histories in this regard, at the same time localised and the outcome of dispersed policies, trends, ways of working, and patterns of investment.

The sited and dispersed making of electricity consumption and supply is particularly evident in the role the 'city' plays as a discursive entity and feature of network planning practices around which future network investments are configured and rationalised (Chapter five and Chapter six). My research also shows that the city is but one discursive entity amongst others , with the region, nation-state and Europe playing roles in the framing of challenges and the ordering of provision (Chapter six). Here, my research echoes Marston's (2000,

p. 220) argument that scale is ‘implicated in the production of space’. However, my contribution is to show specifically how many discursive scales are implicated in the constitution of electricity demand, featuring as discursive and sensemaking aspects of network planning practices.

In the terms described, literal and discursive scales are a common theme and feature of how electricity consumption and supply take shape together. In a situated way, consumption and supply meet in and are shaped by the nuances of local settings, their histories and organisation. Yet, such localised junctions between consumption and supply are also informed and structured by dispersed policies, trends and events that are clearly not local or of a site. More than this, multiple discursive scales, mobilised by network planners, are used as part of the structuring of electricity supply and facilitating consumption.

Temporality: Uneven periods and moments of electricity demand and supply

Temporality is also an important aspect of my account of the dynamic constitution of electricity demand in Central Manchester since 1984. This is because my research shows that multiple practices and related policies, trends, events and material capacities and thresholds combine over time and as constitutive features of electricity demand. There is a lot going on here, with each feature understood to have its own trajectory and history, which weave together, combining over time, making multiple periods and moments of urban development and infrastructural extension.

The liberal turn in town planning, evident in the early 1980s, was not on its own enough to trigger the residentialisation of cities across the UK. This trend instead picked up pace after the turn of the millennium, with other trends proving relevant as well. At a broader UK scale, these include the introduction of the Buy-to-let mortgage in 1996, the liberalisation of higher education coming into the millennium, and the emergence of a liveable cities movement. In Central Manchester, the build-up to and delivery of the Commonwealth Games, over a seven-year period (1995 - 2002), and the recovery from the IRA bomb post-1996, feature as more unique moments, with different histories, yet both part of the city's residential and commercial development. This uneven pattern of urban development and the spatial reordering of electricity consumption is further mirrored in the electricity system's change. The Central Manchester Primary Substation was built in 2009, but until then much of the city's urban development had made new and different use of existing infrastructure. Neither the IRA bomb nor the Commonwealth Games were enough to occasion the Central Manchester Primary. Only when an accumulation of policies, trends and events combined, was this moment of network investment necessitated.

As is well documented, the constitution of electricity demand thus has a dynamic history (Hughes, 1983). My account specifically shows, however, that this history is not linear but punctuated, with consumption and supply taking shape unevenly over time, as a consequence of intersecting practices, associated policies, trends in investment and events, each with their own histories.

Multiplicity: Multiple practices inform the constitution of demand

Multiple practices, associated scales and periodicities, 'knot' together in and inform the constitution of electricity demand in Central Manchester. This theme connects with Massey's (2005, p. 55) argument that a 'discrete multiplicity' underlies the production of space. Developing this point, the metaphor of knotting is particularly useful because it captures the idea that the ordering of and the co-constitutive relationships between electricity consumption and supply are the outcomes of multiple practices that tie together over time. These practices include those connected with trends in town planning, dominant imaginaries of the city, patterns of investment, the ordering of higher education, and the management of the electricity network by different stakeholders. As discussed, these practices and associated trends are typically dispersed, yet they meet and intersect in sites, such as Central Manchester, producing periods and moments of urban development and large-scale infrastructural investment.

Both the residentialisation of the city centre, between 2000 and 2012, and the arrival of the Central Manchester Primary in 2009, reflect different and yet connected empirical examples of knotting. The residentialisation of the city centre was well underway before the arrival of the Central Manchester Primary, as a consequence of multiple intersecting practices and associated trends. The Central Manchester Primary was occasioned at a specific moment and, in part, by the conjunction of practices and associated trends that informed the city centre's residentialisation. Yet, the addition of the Central Manchester Primary also reflects longer-term expectations and changing here and now demands, not only to do with the city's ongoing residentialisation. The impending or at least anticipated use of more electric vehicles and the city's vision of economic growth represent, for example, other threads connected with the Central Manchester Primary's development. Similar dynamic processes and conjunctions are evident in the wider organisation of electricity infrastructure, with various trends, informing periodic changes in the patterning of demand and the organisation of supply which register at particular discursive scales and inform infrastructural investment.

The narrative here is not one of the progressive tightening up of a system, but of its repeated reconfiguration, alongside and in reference to various knots of consumption and situated network thresholds. I am also not suggesting that knots are fast-frozen; previous knots can be, and are, undone over time. This is clear from Manchester's land use change and the electricity system's extension over time. Land use changes not only signal the knotted outcome of present practices and associated trends but also the untying of past combinations that informed certain developments. Likewise, instances of network investment represent fresh knots, anchored in space and time, which see material reconfiguration as opposed to stubborn resilience. The formation of electricity demand is thus not an ongoing and unending process of retying old knots. Instead, some knots will prove more durable than others, holding in place certain forms of land use and hardware, while others will dissipate over time, due to new comings together and combinations of practice.

Intersections of infrastructure and practice

Bringing the themes discussed together, I have shown the coexisting ebb and flow of change and stability within, across and between different 'registers' of consumption and supply. I have described, on the one hand, periods in which there seem to be bursts of land use change (taken throughout as proxies for practice bundles) and, on the other, periods of only occasional large-scale infrastructural investment. This coexisting ebb and flow of change and stability across registers of consumption and supply foregrounds the different scales and periodicities at play as part of the ongoing constitution of electricity demand. Key here is the idea that scales and periods of change and stability within, across and between systems of provision and practices of consumption coexist, enable, and respond to each other but crucially not always in tandem. Taking the ideas and themes discussed a step further, I now turn to a discussion of what my account means for and suggests about the future constitution of electricity demand in Central Manchester.

Thinking about and 'seeing' the future of electricity demand in Central Manchester

Following Massey (2005), an active multiplicity lies at the core of this thesis. And, one clear conclusion is that the future constitution of electricity demand in Central Manchester is not predetermined. This is not a novel suggestion: electricity consumption and supply quite obviously have to be made (Hughes, 1983; Frost, 1993; Verbong and Geels, 2007, 2010; Harrison, 2013; Shove and Walker, 2014). What is novel, however, is what my account suggests about how the future constitution of demand and the electricity system will take shape. And, what my account means for those interested in conceptualising, studying or shaping demand and large-technical systems, be they academics or professionals.

My research has a bearing on discussions of future supply and demand in that it implies that the future constitution of demand can be 'seen', at least to some extent, by working with and drawing connections between purposeful statements, outlined in various plans, policies and strategies. As others have shown, the spatial and temporal scope of plans and strategies, and their enactment, make certain futures more likely than others (Litman and Colman, 2001; Noland, 2001; Fabini et al., 2014; Spurling, 2019). It thus makes sense to return to such documents to develop an understanding of the making of future demands in the present.

As demonstrated in Chapter four ('(Not)made in Manchester') and Chapter six ('The organisation(s) of electricity system(s)') of this thesis, purposeful statements refer to different discursive scales, including the city, region, country and beyond. Central Manchester is caught up in each of these frames and for this reason 'seeing' the future constitution of demand in the city is not only about studying 'local' plans. Indeed, my account shows that it is crucial not to take plans in isolation, but instead to read them in conjunction and to make connections between them and what they suggest in combination about the linked organisation of activity and electricity supply. The multiplicity at the core of my account also means that it makes sense to look beyond purposeful statements directly connected with energy policy. As others have shown, non-energy policies, that is policies that matter for energy demand but that are not specifically about energy, are just as important for thinking about the constitution of demand (Royston et al., 2018). Relevant examples might include housing policy, higher education policy or policies regarding economic growth.

Before proceeding and sketching out what appear to be features that have a bearing on the future of electricity demand in Central Manchester, a word of caution needs to be noted. Purposeful statements tend to form propositions, linked with specific outlooks that are yet to be brought into fruition or to actually have an effect. The following should, therefore, be read as a discussion of as yet unrealised visions that are likely to shape electricity demand and electricity supply in Central Manchester.

Anticipating the future of electricity demand in Central Manchester

A review of official plans, statements and documents concerning planning, housing, and transport suggests that there is likely to be a continuing concentration of residential and commercial activity, and linked electricity demands, in Central Manchester (Greater Manchester Combined Authority (GMCA), 2017, 2019; Manchester City Council (MCC), 2017, 2018b; Transport for Greater Manchester (TfGM), 2017a, 2017b; Barker, 2019; Conservative Party, 2019; HS2, 2019; Deloitte, 2020). The continuing residentialisation of the city connects with the Greater Manchester Combined Authority's (GMCA) plan to support the building of 10,000 new homes in the metropolitan region in ten years (GMCA, 2019). The current and persistent cutting of 'red tape' by the national government, as part of simplifying the planning process will make it easier for the GMCA to achieve this aim, with fewer restrictions over where residential developments can take shape (Barker, 2019; Conservative Party, 2019). Fitting with and going beyond GMCA's backing of 10,000 new homes in ten years, there are currently 12,357 residential units under construction across the city centre and Salford (Deloitte, 2020).

The ongoing constitution of this residential electricity-demanding geography depends on Manchester continuing to provide favourable rates of return on investment – a central component of developer and investor activity (Harper, 2014; Hall, 2018; Property Investments UK, 2019). In this respect, the GMCA's use of a '£300 million housing fund', which formed part of the Greater Manchester Devolution Agreement, helps make the region an attractive place to invest (GMCA, 2017). This fund provides developers with a cheap loan stream of monies up to £30 million (GMCA, 2017).

For Central Manchester to continue becoming a residential hotspot, the city will also have to remain a site in which people are willing to live and work. Established strategies and plans to make the city 'liveable' are important in this respect (MCC, 2017, 2018b). As is the desired and forecasted growth of universities around the UK and in Manchester (House of Commons Libraries, 2019; Weale, 2019; University of Manchester, 2020). Indeed, the commitment to a liveable city agenda and the growth of HE will play into, support, and spur on the development of a city increasingly marked out by residential electricity demand.

In tandem with and supporting the city's continuing residentialisation, plans are in place to make sure Manchester remains a commercial success. Calculations of Gross Value Added (GVA) show that the Greater Manchester region currently has a larger economic output than Wales or Northern Ireland (GMCA, 2019). The economic success of the metropolitan region involved, as shown in Chapter one, a concentration of commercial activity in Central Manchester (Thomas et al. 2015; UrbInfo, 2019). This is set to continue, with forecasted GVA growth dovetailing with national and local plans that support the continuing concentration of commercial activity in the city centre (MCC, 2018b).

Transport policies are particularly relevant in this regard. At a local scale, the ongoing and planned expansion of the Metrolink tram network aims at stimulating ‘economic growth and housing market renewal in Greater Manchester’ (TfGM, 2017a, p. 52). In theory, these changes will enable greater interconnectivity between sites and the people, businesses and practices that populate them, continuing Transport for Greater Manchester’s (TfGM) aims to corral the ‘city region’s ten boroughs in pursuit of… economic priorities, [by] bringing commuters into key commercial and industrial districts such as the city centre’ (Odling, 2017).

Likewise, national transport plans and policies also support the idea that Central Manchester’s commercial and residential development is set to continue. HS2 (a major high-speed rail project) is specifically aimed at fostering connectivity between cities to spur on economic growth (HS2, 2019). It is argued that the service will stimulate growth by enabling businesses and people to circulate between and settle in a number of cities, including Manchester (HS2, 2019). The project is scheduled to reach Manchester by 2033 and is expected to bring 180,000 new jobs to Greater Manchester by 2040, ‘adding £1.3bn to the regional economy’ (HS2, 2019). In the city centre, the HS2 project has been connected with the ‘regeneration of the Mayfield district adjacent to Manchester Piccadilly station’ (HS2, 2019). This regeneration project ‘is expected to deliver over 6,500 new jobs and 1,330 new homes in the area’ (HS2, 2019). HS2 is further connected with the ongoing regeneration of the wider Piccadilly area of the city centre, which is estimated to deliver ‘4,500 new homes and over 700,000 sq.m of commercial and retail space’ by 2040 (HS2, 2019). In these terms, the HS2 project is directly connected with the city centre’s commercial and residential growth.

If the ambitions outlined in these national and local transport and housing plans are realised, there will be significant implications for electricity consumption and supply in Central Manchester. More residential and commercial demand will require and see more substations, of various sizes, populating the area. Likewise, anticipated increases in electric vehicles and the expansion of electrified rail services, such as HS2 and the Metrolink, will likely depend on increasing the electricity network's capacity, as such changes have in the past (TfGM, 2017b).

The future of electricity supply in Central Manchester will thus be shaped as a consequence of the city centre's expected, desired and sited residential and commercial development. Yet, my account of the constitution of demand in Central Manchester also suggests that the future of the electricity infrastructure that supplies the city will continue to be an outcome of the enactment of different versions of the network, linked with specific organisations, the professional practices of engineers and network planners, and how demands, problems and challenges are framed and responded to. In this respect, future-oriented plans and strategies again prove a useful means of thinking about changes to come.

Future network plans developed by ENW are set out in the company's *Distribution Future Electricity Scenarios and Regional Insights* publication (ENW, 2018b). Within this document, the company's regional network is broken up into four mini-regions (ENW, 2018b). Each of these regions has its own social and physical characteristics and these are used when identifying future challenges and when rationalising planned investments. In Central Manchester, the future is expected to involve network expansion to accommodate the city's residential and commercial growth (ENW, 2018b). Network 'smartification', to enable forecast increases in electric vehicles and combined heat and power technologies, is a particularly pressing issue given the city's expected commercial and residential development.

However, this is not to say that the future trajectory of the electricity network that serves Central Manchester will only reflect expected changes in the city and the discursive framing of demand at the urban scale. At the same time, it is important to retain and recognise 'the large scale' as a discursive formulation, and as a materialised ‘entity’ – evident in the sizing and design of the grid at various scales. Other network plans, produced by the European Network of Transmission System Operators for Electricity (ENTSO-E) suggest that the future of the network will be little to do with the city itself but instead to do with continuing to facilitate the marketized exchange of electricity across and beyond Europe (ENTSO-E, 2018a).

Key here is the idea that even common aims, such as the need to respond to the anticipated uptake of EV’s and combined heat and power systems, will be enacted and shaped in reference to different discursive scales and timeframes (GMCA, 2016; ENW, 2017a, 2017b, 2017c, 2017d, 2018b, 2018c; ENTSO-E, 2018a, 2018c; National Grid, 2018a; TfGM, 2018). In these terms, the future of the electricity infrastructure and supply in Central Manchester, like consumption, will thus not only be made in Manchester. Instead, demand and multiple parts of what count as ‘the network’ will continue to be constituted through intersections between a multiplicity of practices, related trends, scales and periodicities. Having articulated this account of what my research means for and suggests about the future constitution of demand in Central Manchester, I conclude by considering the implications of this project for researchers and professionals and the types of questions it provokes.

Implications for researchers, policy makers, town planners, and network planners

I have shown that it makes sense to conceptualise and approach electricity demand as an outcome of a multiplicity of relationships, which cut across and take shape at different scales and over various periodicities. For energy researchers, a key implication is that understanding the constitution of energy demand is about discerning and studying the spatial and temporal relationships between multiple practices and how they structure consumption and supply at different scales, over time.

For policy makers and town planners, the implications of this thesis are different. National and local policy makers and town planners have an ambiguous place in my account of the constitution of demand in Central Manchester. National policies certainly shape and filter through local government approaches, taking on sited nuances, which inform the use of land and the organisation of activities in ways that affect energy use and supply. As others have shown, these are not necessarily energy policies in name (Royston et al., 2018). As I have shown, policies connected with planning, housing and higher education, also affect electricity consumption and supply, spurring on, for instance, situated instances of network extension (the Central Manchester Primary, for instance). Given the links between increased provisioning and growing demand (Hughes, 1983; Cass, 2018; Shove and Trentmann, 2018), for policy makers and town planners, it is thus important to identify the latent effects of strategies and to think about whether and how these could be mitigated for the benefit of reaching key energy targets.

This being said, my account also complicates the idea that attempts to mitigate energy use could be informed by more sensitive, nuanced, and better policy alone. As I have shown, national and local policy makers and town planners are not totally in control of the city, electricity consumption or supply. My discussion of Manchester's residentialisation, since the turn of the millennium, shows, for example, that unexpected events, such as the 1996 IRA bomb or the internationalisation of HE (which are clearly not only about policy), have had consequences for patterns of energy demand over time. Likewise, electricity supply is not only to do with national and local policy or town planning, with various organisational aims and commitments informing network developments.

For policy makers and town planners, the practical implications of my thesis are therefore complicated. On the one hand, my research suggests that policy makers and town planners are well placed to (and do) inform electricity demand and supply. On the other, these groups are only elements of and are not in control of the multiplicity of relations and trends that shape demand and supply. Admitting that this is the case challenges the tendency to position local and national policy makers and city authorities as particularly well placed to steer clean energy transitions (Betsill and Bulkeley, 2006; Rosenzweig, 2011; Bulkeley et al., 2014; Carter et al., 2015; C40, 2019; Core Cities UK, 2019). This is not necessarily negative; recognising the limited role of policy makers and town planners could lead to fruitful discussions about where and how demand and supply take shape and what is called for in response.

For network planners, my thesis shows that those involved in this sector are not always responding to the same issues or making the same 'network' in response (Chapter six). At times, local changes, framed with reference to the needs of the 'city' inform network extension. In other instances, what are deemed to be insufficient asset capacities structure investment. Meanwhile the international production, management, regulation and exchange of electricity also appears to shape infrastructural change over time. This account raises questions about how the work of network planners and the enactment of different versions of the network they are involved in are making certain futures more likely than others. For example, does the tendency, at a regional scale, to delay investment until existing capacity is at the limit restrict the spread of renewable forms of distributed generation (DG) and the uptake of cleaner technologies? And, does the continuing commitment to making an increasingly interconnected international network hamper the much-desired development of local city networks as part of the UK's 'clean energy' transition (BEIS, 2017b)?

These types of questions, informed by the approach taken in this thesis, point to new avenues of research. This thesis has focused on the changing relation between electricity supply and demand. However, similar strategies could be developed with respect to other forms of demand, including transport, water and gas. In this regard, the conceptual and methodological steps taken, and the ideas generated along the way promise to be of use beyond Manchester, and beyond the sectors and relations I have examined.

Abbreviations

Association for the Greater Manchester Combined Authority (AGMCA)

Assured Shorthold Tenancy (AST)

Bulk Supply Point (BSP)

Business, Energy & Industrial Strategy (BEIS)

Buy-to-let (BTL)

Commonwealth Games Federation (CGF)

Department for Energy and Climate Change (DECC)

Department of the Environment, Transport the Regions (DETR)

Distributed Generation (DG)

Distribution Network Operator (DNO)

Electric Vehicles (EV)

Electricity (Connection Charges) Regulations

Electricity North West (ENW)

Energy Networks Association (ENA)

European Network of Transmission System Operators for Electricity (ENTSO-E)

Greater Manchester Combined Authority (GMCA)

Grid Supply Point (GSP)

High Voltage (HV)

Higher Education (HE)

International Energy Agency (IEA)

Kilovolts (kV)

Kilo-volt-ampere (kVA)

Land Use Change Statistics (LUCS)

Large Technical Systems (LTS)

Low Voltage (LV)

Lower Level Super Output Area (LLSOA)

Manchester City Council (MCC)

Manchester Millennium Taskforce (MMT)

Megawatt (MW)

National Grid (NG)

National Grid Electricity Transmission (NGET)

Northern Quarter (NQ)

Office of Gas and Electricity Markets (OFGEM)

Office of National Statistics (ONS)

Office of the Deputy Prime Minister (ODPM)

Ordnance Survey (OS)

Science and Technology Studies (STS)

The Organisation for Economic Co-operation and Development (OECD)

United Utilities (UU)

Vaults (V)

Appendices

Appendix 1: Participant information sheet

<u>Participant Information Sheet</u>

Project Title:

The Dynamics of Energy Demand in Central Manchester

Project Information:

My name is Torik Holmes and I am a PhD student within the DEMAND Research Centre at Lancaster University. The DEMAND Centre studies the dynamics of energy, mobility and demand. My project specifically looks at the relationship between changes in land use and the development of electricity infrastructures in the Northern Quarter (NQ) between 1980 and present day.

I would like to invite you to participate in this study by taking part in an expert interview. This participant information sheet is designed to tell you about the purpose and focus of my research which concerns the changing relationship between the use of land – e.g. for businesses, housing, retail etc. - and the development and management of electricity infrastructures.

If you have any further questions after reading this document, please do not hesitate to send me an email or give me a call.

What is the study about?

Broadly, this study is about the development of Manchester and how changing land use relates to and affects the management of electricity infrastructure. More specifically, I focus on a segment of Manchester, the NQ, and investigate how that area has changed since 1980, and how such changes relate to the development of the electricity network.

A little more detail:

In many ways, the history of the NQ mirrors that of Manchester as a whole. The NQ is an area that still contains remnants of the industrial revolution, whilst also accommodating new uses, including residential and commercial buildings. At the same time, the NQ is a distinctive area within the city centre, having become known for its historical buildings, and more recently for its independent shops, cafes and bars. Focusing on the NQ as part of Manchester's urban history, my research asks how changes in the use of land and the types of activities taking place in the area have depended on and possibly affected electricity infrastructure. For example, how did the rapid rise in the number of people living in the NQ, between 2001 and 2011, affect the management of the electricity networks? How do shifts in planning processes affect the development of electricity infrastructure? What are the consequences of changing land uses on electricity infrastructures? How do changes in patterns of demand affect the electricity grid? These are important questions, which concern sustainable urban development and attempts to reduce electricity demand in the city.

In order to answer such questions, I need to talk to people, like you, who have worked within Electricity North West (ENW) or the Manchester City Council's (MCC) Planning and/or Regeneration teams.

Why have I been approached?

You have been approached because you work for/have worked for (select which applies) ENW or in the Planning or Regeneration teams within Manchester City Council (MCC) at some point between 1980 and 2017. Although I am focusing on the NQ, this area is obviously part of city-wide infrastructural networks. I am therefore interested in talking with people who also know about the development and management electricity infrastructures across Manchester as a whole.

When and where is the research taking place?

The interviews will be taking place between July 2017 and December 2017. If you are willing to be interviewed, we can arrange a place and time to meet at your convenience.

What will the interviews entail?

Interviews will last up to 90 minutes and entail a discussion of some of the following key themes: (include only those which apply)

Planning and Regeneration:

- What you know about the urban planning and development of Manchester between 1980 and 2017.
- The development of the NQ between 1980 and 2017.
- The planning process, particularly in relation to developments in the NQ since 1980. For example, processes surrounding the publications of *The Core Strategy Development Plan* and *The Northern Quarter Development* Framework.

- The role of MCC and other stakeholders in steering the development of the NQ between 1980 and 2017.

ENW:

- The historical development of the electricity network in and around the NQ and Manchester from 1980 onwards.
- A consideration of when and why changes to the grids have occurred over this period.
- A discussion concerning how changing land uses, in the NQ and Manchester City Centre, have altered the development of the grid, and vice versa.

What will happen to the interview material?

Interview material will be transferred from an encrypted voice recorder to a password protected and encrypted hard drive at Lancaster University. The audio file names on the hard drive, will not refer to the interviewees' identities.

Your interview data will be transcribed, with each transcription saved on Lancaster Box, and the encrypted and password protected hard drive. The transcriptions will not refer to your identity and will be saved in a different file to the audio recordings. Only the interviewer will have access to the audio recordings, each of which will be deleted after it has been transcribed.

The transcriptions will be stored on Lancaster Box for minimum of 10 years, as per the University's Research Data Policy guidelines. Your data will be kept for this length of time to preserve the information discussed. The transcriptions and a selection of relevant research documents will also be uploaded to the UK Data Archive. This will enable other researchers, upon request, to use the material. Again, complete anonymity will be maintained. For more information concerning the UK Data Archive, please see: http://www.data-archive.ac.uk/. Transcriptions saved on the password protected and encrypted hard drive will be deleted one year after the submission of the research thesis (no later than September 2019).

The researcher and the two research supervisors will have access to the interview transcriptions. Parts of the transcribed interviews will appear in my thesis and possibly in professional publications, such as journal articles. Aspects of the interviews may also feature in presentations. At all times, interview content will be anonymised and pseudonyms used in any published material.

Are there any risks?

As an interviewee, you may still be working for MCC or ENW and you may feel that some of the questions touch on issues that present a conflict of interests. You do not need to answer any such questions and if there are areas you would rather not discuss, they will not be pursued.

What will happen if I do not want to carry on with the study?

If you no longer wish to participate in the study, you will not be asked why and will no longer be contacted. If you have already completed an interview and it has been anonymised, it may be difficult to locate and retract the data. It is advised that you let the interviewer know that you do not want to continue within 2 weeks of your interview.

Who is funding this project?

This project is a part of the DEMAND Research Centre's work. The centre is funded by the Engineering and Physical Sciences Research Council (EPSRC) and the Economic and Social Research Council (ESRC). DEMAND focuses on what energy is used for and how energy demand could be reduced.

What if something goes wrong or I want to make a complaint?

If something goes wrong, you can contact Dr Stanley Blue who is co-supervising the research project and works within the DEMAND Centre. Alternatively, if you want to speak to a member of staff outside of DEMAND, you can contact the Dean of the Faculty of Arts and Social Science, Professor Simon Guy. Please see their details below:

Dr Stanley Blue,
The DEMAND Centre Lancaster University,
Tel: 01524 595 113
Email: s.blue@lancaster.ac.uk

Professor Simon Guy,
The Faculty of Arts and Social Science Lancaster University,
Tel: 01524 592 760
Email: s.guy@lancaster.ac.uk

Consent process:

If you would like to take part in the research project and be interviewed, you will need to sign a consent form, which I will bring when we meet. You will keep one copy of your signed consent form, whilst another signed copy will be kept in the Research Site File. If you do not already have one of these, send me an email and I will get one over to you as soon as possible. Alternatively, if you would like to discuss the research further before committing, you can contact me or visit my website for more details.

Torik Holmes

Email: t.holmes@lancaster.ac.uk

Website: torikholmes.wordpress.com Mobile: 07742 793 012

Appendix 2: List of local and national planning policies, strategies, acts and reports worked with as part of Study two

- Central Manchester Development Corporation (1990) *Development Strategy for Central Manchester*
- *Local Government, Planning and Land Act 1980*
- Manchester 2002 Limited (M2002) (2002) *A Games Legacy for Manchester and the North West*
- Manchester 2002 Limited (M2002) *Post Games Report Volume 1*
- Manchester 2002 Limited (M2002) *Post Games Report Volume 5*
- Manchester City Council (MCC) (2003) *Northern Quarter Development Framework*
- Manchester City Council (MCC) (1945) *City of Manchester Plan 1945*
- Manchester City Council (MCC) (1961) *Development Plan for the County Borough of Manchester*
- Manchester City Council (MCC) (1967) *Manchester City Centre Map*
- Manchester City Council (MCC) (1984) *Manchester City Centre Local Plan*
- Manchester City Council (MCC) (1995) *The Unitary Development Plan for the City of Manchester*
- Manchester City Council (MCC) (2002) *Task Force Final Report*
- Manchester City Council (MCC) (2004) *Manchester City Centre Strategic Plan 2004-2007*
- Manchester City Council (MCC) (2009) *A Strategic Plan for Manchester City Centre 2009 – 2012*
- Manchester City Council (MCC) (2012) *Manchester Core Strategy 2012 to 2027*
- *Town and Country Planning Act 1947*
- *Town and Country Planning Act 1990*
- UK Public General Acts (1988) *Housing Act 1988*
- Urbanistics (1994) The *Northern Quarter Regeneration Study*

Appendix 3: Energy plans, strategies, reports and policy documents worked with as part of Study four

- Association of Greater Manchester Authorities (AGMA) (2011) *The Greater Manchester Climate Strategy 2011 – 2020*
- Association of Greater Manchester Authorities (AGMA), URBED, AECOM and QST (2010) *Decentralized and Zero Carbon Energy Planning*
- Deloitte (2008) *Mini-Stern' Report for Manchester*
- Greater Manchester Combined Authority (2016) *Climate Change and Low Emissions Strategies' Whole Place Implementation Plan for Greater Manchester*
- Electricity North West (ENW) (2017) *Demand Scenarios and Innovation Projects at Electricity North West*
- Electricity North West (ENW) (2017) *Electricity North West: Strategic Direction Statement 2017*
- Electricity North West (ENW) (2017) *Annual Report and Consolidated Financial Statements for the Year Ended 31 March 2017*
- Electricity North West (ENW) (2017) *Long Term Development Statement November 2017*
- Electricity North West (ENW) (2018) *Distribution Future Electricity Scenarios and Regional Insights*
- Electricity North West (ENW) (2018) *ENW Innovation Strategy*
- Electricity North West (ENW) (2018) *Getting Connected: A Common Charging Methodology*
- Electricity North West (ENW) (2019) *Generation Connected to the Electricity North West Distribution Network*
- Energy Technologies Institute (2016) *Greater Manchester Spatial Energy Plan*
- European Network of Transmission System Operators for Electricity (ENTSO-E) (2017) *Annual Report 2017*

- European Network of Transmission System Operators for Electricity (ENTSO-E) *The Future of the EU Grid and the Role of AC and DC Technologies*
- European Network of Transmission System Operators for Electricity (ENTSO-E) (2018*) In-Short: Regional Investment Plans*
- European Network of Transmission System Operators for Electricity (ENTSO-E) (2018) *TYNDP 2018 - Project Sheets*
- Greater Manchester Energy Group (2011) *Connected: The Greater Manchester Energy Plan*
- Manchester City Council (2005) *Manchester's Energy Strategy for 2005 – 2010*
- Manchester City Council (2008) *The Principles of Tackling Climate Change in Manchester*
- Manchester City Council (2009) *Manchester Climate Change: Call to Action*
- Manchester City Council (2009) *Manchester: A Certain Future*
- Manchester City Council (MCC) (2010) *Manchester's Climate Change Delivery Plan 2010 – 2020*
- Manchester Climate Change Agency (2013) *Manchester: A Certain Future*
- Manchester Climate Change Agency (2016) *Manchester Climate Change Strategy 2017-2050*
- National Grid (NG) (2017) *National Grid Electricity Transmission plc Annual Report and Accounts 2016/17*
- National Grid (NG) (2018) *Future Energy Scenarios System Operator*
- National Grid (NG) (2018) *Annual Report and Accounts 2017/18*

Appendix 4: How I extracted and mapped Land Use Change Statistics

Each recording of a change of land use in the LUCS datasets (ONS, 2017a, 2017b) are coded with a land use classification. Each recorded change also includes information of eastings and northings coordinates, which make it possible to plot instances of change on a digital map.

The datasets I received contained all land use changes occurring within the bounds of Manchester City Council's (MCC) local authority region between 1984 and 2014. In order to extract instances of change occurring in the Northern Quarter (NQ) and to remove changes that occurred outside of the area, I marked out the extremities of the NQ on a digital map. Figure 34 shows four pins, which I plotted on gridreferencefinder.com to complete this task.

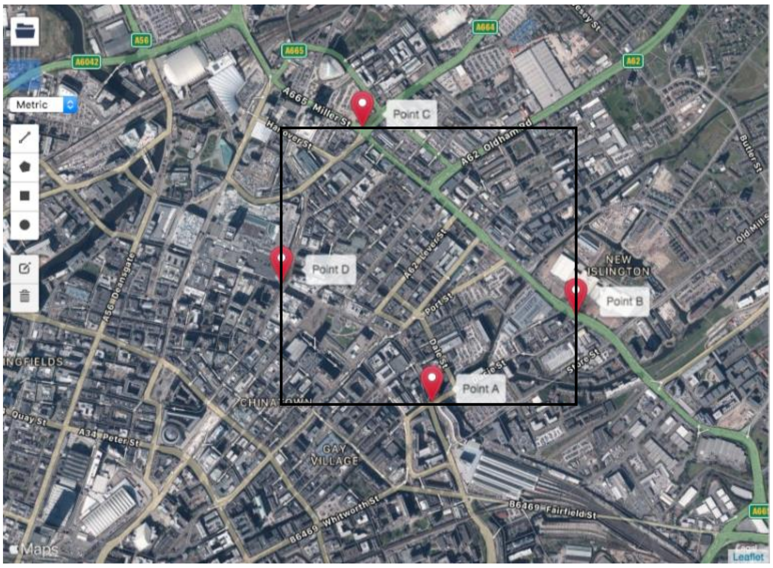

Figure 34: The extremities of the NQ plotted on: http://gridreferencefinder.com

Grid Reference	X (Eastings)	Y (Northings)	Latitude	Longitude	Description (Click to Edit)	Address	Postcode	Link	Center	Zoom	Style (click to change)	Show	Delete
SJ 84647 98054	384647	398054	53.47898:	-2.232802	Point A	Ducie Street, Piccadilly, City Centre, Manchester, Greate	M1 2HX					✓	
SJ 85085 98316	385085	398316	53.481351	-2.226215	Point B	Eternal Life Sanctuary, 126, Great Ancoats Street, Ardwic	M4 6DE					✓	
SJ 84439 9888:	384439	398885	53.48644(	-2.235977	Point C	Swan Street, NOMA, Strangeways, Manchester, Greater I	M4 4AF					✓	
SJ 84193 98416	384193	398416	53.48222:	-2.239661	Point D	Market Street, City Centre, Manchester, Greater Manche	M60 1TA					✓	

Figure 35: The accompanying coordinates of each land use change plotted on: http://gridreferencefinder.com

The points marked out on Figure 34 show the highest and lowest eastings and northings coordinates of the NQ (also see Figure 35). The most southerly point on Figure 33 is point A, which has the northing coordinate 398054. Point C marks out the most northern point – which has the northing coordinate 398885. The information I needed to extract fell within the northings range between 398054 (point A) and 398885 (point C). Returning to each dataset, which contain all instances of land use change occurring in Manchester's local authority, and sorting the northing's field in an ascending order, I was able to extract changes occurring between 398054 and 398885. I repeated the same process using the easting coordinates related to pins B and D, which are also shown on Figure 33. Having completed this process, I had sorted the changes that occurred inside the square boundary shown on Figure 34, from those that did not.

However, because the NQ is not an exact square, the reduced dataset still contained points of change falling outside the NQ (Figure 36 shows the NQ as it sits within the larger geographical square that demarcates the highest and lowest easting and northing coordinates of the area).

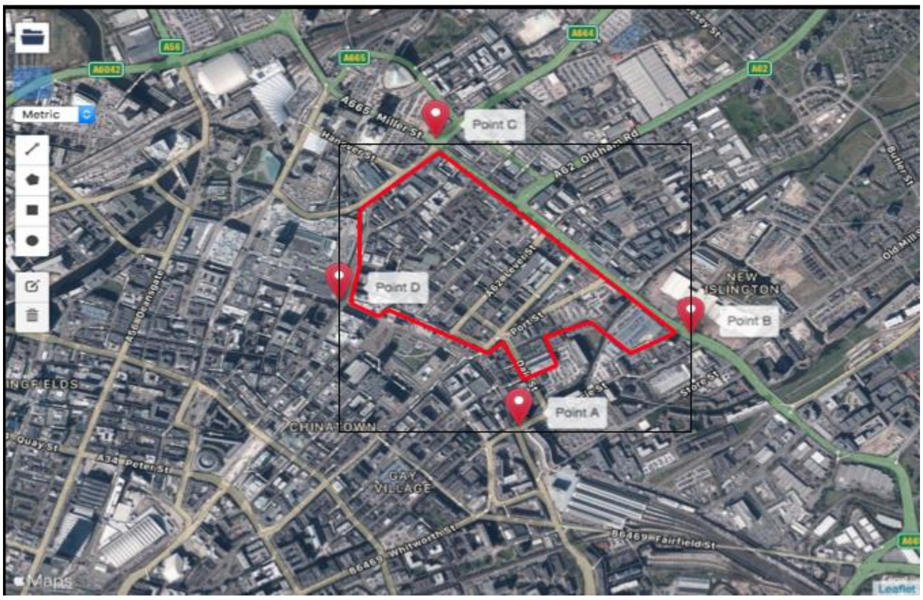

Figure 36: The NQ placed in larger geographical square

In order to sort the changes that occurred within the bounds of the NQ, I plotted, on a digital map, all of the changes occurring within the square area represented by Figure 34. To do this, I converted the eastings and northings to longitudinal and latitudinal coordinates on gridreferncefinder.com. I then downloaded the KML file containing each change’s longitudinal and latitudinal coordinates and imported them onto a Google map. With all the points plotted, I manually deleted entries that fell inside the wider geographical square but outside of the NQ. Because each entry plotted was listed in the same numerical order as they appeared on the excel datasets, I was able to quickly find and remove entries from my reduced spreadsheets. I followed this process for each of the datasets I received from the ONS. Figure 7, in Chapter one represents the forty-two changes to a new use of land in the NQ that unfolded between 1984 and 2012.

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